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COOPERATION IN RESETTLEMENT AND RURAL REHABILITATION[1]

(Palestine and Saskatchewan)

by

Henrick F. Infield
Rural Settlement Institute, Van Wagner Rd., R.R., Poughkeepsie, N. Y.

Cooperation, as standardized in the so-called Rochdale Principles, is one of the techniques applied today to the solution of problems in resettlement and rural rehabilitation. The success of this technique depends largely on the full and active participation of those who are to benefit from it. Administrators, particularly when working under budgetary compulsions, are likely to neglect this important aspect of cooperative association, often - as in the case of the F.S.A. cooperative farms - with anything but favorable results. It may be useful, therefore, to consider briefly what happens when a group of people resort to cooperation out of their own free decision. Two instances of such development, one well established and the other apparently of real promise, exist today. One is the Kvutza (or Kibbutz) which grew out of the Zionist resettlement enterprise in Palestine; the other is the Saskatchewan cooperative farms, embodying a trend toward rural self-rehabilitation in that Canadian prairie province. The key to the understanding of both developments is their "human element". This, in the case of the Kvutza - to which we turn first - is that of the Zionist immigrants.

The Zionist Immigrants.

As in all population movements, the forces of what has been called "push and pull" have been active, too, in Jewish immigration to Palestine.

The forces of "push" were of an economic, cultural and political nature. When in the 1880ies the industrial revolution reached eastern Europe - the part from which most of the immigrants came - it made precarious most of the occupations open to the Jewish population. Their economic basis became so airy that the term "Luftmensch", the man who apparently lives on air, came to signify a dominant type of the eastern Jewish "economic man". The impact of secular ideologies, most attractive among them socialism, broke the unifying hold of orthodox tradition. The political exploitation of anti-semitism, manipulating antagonism against the "out-group" into programs of bestial violence, endangered life and limbs of the defenseless.

As usually happens, the main stream of emigration followed the "pull" exerted by countries promising most in terms of economic betterment, chiefly the U.S.A. A minor, but significant, part of the emigrants, composed mostly of University youth, chose to move towards a different goal, that of Jewish statehood in Palestine.

Conditions of Resettlement.

When, aided by the Zionist Organization - established in 1897 under the leadership of Theodor Herzl - the eastern Jewish youth, intent on building the National home, reached Palestine, it found itself beset by ideological as well as by material difficulties. Both were considerable.

A merciless climate, swampy or eroded soil, and unsanitary conditions had to be coped with by city bred youth, almost completely unversed in agrigultural skills. Placed on individual farms, only a few were able to stand up to the strain of unaccustomed work and living conditions; the large majority had to admit defeat.

Motivated by socialist concepts, others by principle declined to become owners and exploiters. They hired themselves out to farmers in the few Jewish villages, previously established with the aid of philanthropic funds. These farmers adhered strictly to orthodox tradition, while the new immigrants were moved mainly by nationalistic ideals and free-thinking socialism. When in the village of Petach Tikvah one of the newcomers was caught smoking a

1. Paper read before the Spring Meeting of the Society for *Applied Anthropology*, Philadelphia, Pa., May 28-29-30, 1948.

cigarette on Sabbath, open conflict broke out, which led to the exodus of the whole "class-conscious" group.[2]

Faced by these failures, the Palestine Office, headed by Dr. Arthur Ruppin, realized the need for a fundamental re-orientation of its colonization policy. The question was, as Dr. Rupping himself later recorded, not either individual or group settlement, but either group settlement or no settlement at all.

The idea of cooperative settlement had been first advocated for Plaestine by Dr. Franz Oppenheimer, the noted German sociologist. When individual settlement failed, Dr. Oppenheimer was given an opportunity to translate his ideas into reality. Proceeding from a blue-print, similar to that of socio-reformistic utopians, he established, in 1910, a colony, called Merhavia. Its short existence was beset by conflicts among the members themselves as well as between them and the manager.

The Emergence of the Kvutza.

The Kvutza is the first cooperative community which did not have its origin in a blue-print. It came into existence when some ten of the hired men who had quit the village of Petach-Tikvah took up cooperation because it offered them a solution to their main problem of how to become owner-farmers without becoming exploiters. On their exodus, they reached the Galilee, and were settled on National Fund land as a group, under the management of an expert agronom. This time, conflict arose because the expert handled his position like any other job, while the Zionist pioneers took theirs to be one of historical mission. Again they quit, and decided to set out on their own. A chance to do so was given them at what has since become the Kvutza Dagania A.

At first, they organized themselves as an agricultural production cooperative. They were satisfied to extend cooperation to work only, to share the gains equitably, but to use them as each one pleased. When the first year was over and the time had come to share the profits, they found that there were none; nor could any be expected in the forseeable future. Turning emergency into virtue, they then made a decisive step. They did away with all distinction between mine and thine, and agreed each to work according to his best abilities, and to receive from the common purse as much as was available for his needs.

Experimental Procedure.

Thus, in 1911, the economic basis for the Kvutza was laid. This basic change cleared the way for further innovation. The work on which their existence depended was the tilling of the soil. Whatever hands were available, they were not enough. Yet, each woman took care of her own children, cooked and laundered for her own family. This now appeared as an improper waste of energy. All their property was held in common; why not have one common nursery, one central laundry, kitchen and dining hall for all? They tried it, and it worked. The children were just as well, if not better, taken care of: there was only one day of laundry for the whole group; savings were made on food; and, most important of all, hands became free for productive work.

When the Balfour declaration, in 1917, and the end of the First World War stimulated immigration, the Kvutza was already solidly established. It became the dominant form of settlement, and grew in the following years rapidly in number and in membership.

Then arose the most crucial issue. It concerned the equality of women. Theoretically, their position in the Kvutza was in every respect the same as that of the men. But in practice, as long as the children remained with the parents, it was the mother who was handicapped in the performance of her duties as a worker, particularly so long as the children were very young. Many a long, and often heated, discussion was devoted to the problem. It appeared that there was only one perfect solution: to provide, under the most expert supervision, separate quarters for the children, from infancy to adolescense. The solution aroused strong opposition: some of the women preferred to leave the Kvutza rather than accept it. But once put into practice, separation enabled the woman to take her full share in all activities of the group, without weakening the bond between parents and their children.

Thus, step by step, the Kvutza developed into what it is today, a unique instance of cooperative community which practices the most comprehensive cooperation. Most recent estimates put the number of Kvutzot at 150. At the last official count, end of 1943, there were 108 such communal villages in Palestine, with a total membership of 28.600, and a total area of land of some 120.000 acres. The largest Kvutza, Yagur, had a population of about 1200; the

2. See: Shlomo Zemach: *An Introduction to the History of Labour Settlement in Palestine.* Translated from the Hebrew by Sylvia Satin. Tel Aviv (no year). Lion the Printer. p. 58.

smallest, of twelve; the majority of Kvutzot had a population of between 200 and 400.

Membership.

We shall consider now, briefly, the Kvutza as it functions today.[3]

Membership in the Kvutza is acquired either by joining a group of aspirants who intend to start a new settlement, or by entering one already existing. In the first case, there may elapse a preparatory period of several years before settlement can be accomplished. The minimum number of families required for a new settlement has been set recently at sixty. Any Jewish male or female person, over 16 years of age, adhering to the tenets of the Zionist Organization, is eligible for membership. A period of probation, usually not longer than a year, procedes final admission. The candidate shares all duties and privileges of full members, with the exception of vote. He also retains his personal belongings.

The majority of members hail from Eastern Europe but Jews of "all nations" and of all classes are well represented. The common ideal, a way of life new to all, and the use of the Hebrew language, mould them into a new type, the Kvutza type of Jewry. The rate of turnover is relatively low; 14 per cent in the more recently formed, and only 6 per cent in the older Kvutzot.

Administration and Management.

Internal administration in the Kvutza is relatively simple. Main authority rests with the General Assembly of members which convenes at least once a year. Decisions are made by majority vote. The General Assembly elects committees for all phases of community life; most important are the Management and the Work Assignment Committee. Most committees consist of three or more members elected for a term of one year. Office or administrative functions yield no compensation, either in money or privileges; it is carried on as "extracurricular activity", as a voluntary contribution to the common welfare.

Economically, the Kvutza is literally a world without property. For not only is there no private property in the Kvutza, there is, in the last analysis, no group property either. In case of dissolution, all property of the Kvutza reverts to the national agencies.

The Kvutza owns - only what it produces. Work is therefore the main condition of belonging. Only invalids, the sick, the pregnant, the children and the aged are exempt from work. Agriculture is the principal occupation. Farming is of the diversified type. The Kvutzot are being run as large-scale farms, and they employ the most modern techniques of agriculture and stock breeding. Additional sources of income include industrial enterprises, sometimes run by two Kvutzot together, and work on the outside. The larger the community, the more varied the activities.

Specialization, as well as versatility, finds its place in the Kvutza. The skilled workers are as a rule kept on the job for which they are best fitted: the unskilled form a kind of manpower reserve, distributed to points where they are most needed. "Unproductive" work, such as kitchen duty, is done by all members in turn.

No financial reward is received for work. Money earned outside is delivered to the common purse. There is no work card, no advance wage, and no sharing of profits. Available goods and services are distributed according to need and not according to performance. Absence of the profit motive, however, does not affect work morale. Slacking is relatively rare, and appears to present less problems than "exaggerated devotion to work". The normal work-day is 10 to 12 hours. There is no penalty for absence from work, but work attendance seems to offer no need of any. Only 22 days a year are lost on the average in all Kvutzot because of illness and convalescense.

All Inclusive Cooperation.

All aspects of life in the Kvutza are governed by the spirit of comprehensive cooperation. Since the meals are prepared in a central kitchen and taken in the common dining-hall, the houses are, like in the Hutterite colonies, mere dormitories. The prevailing type of house is the wooden bungalow. The cowbarn, the children's house, and the dining hall are solid buildings, usually concrete or stone. The dining-hall serves also for the meetings of the General Assembly, for lectures, concerts and recitals; but its main function is that indicated by its name. Four meals a day are served here to the adults. The children take their meals in their own living quarters, the children's house. The food is plentiful and

3. For a more detailed description, see the authors: Cooperative Living in Palestine, 1944, N. Y. Dryden Press, and 1946, London, Kegan Paul.

consists mostly of products raised in the Kvutza.

Rich intellectual activity and wealth of recreational opportunities are a specific trait of the Kvutza. A large percentage of Kvutza members -56 per cent among the original founders - have enjoyed higher education prior to immigration. Thus a large part of recreational activities, well led discussions, seminar courses, lectures, dramatic groups, can be maintained from own resources. In addition, the Education Office of the Histadrut procures excellent lecturers, and arranges concert tours by resident or visiting artist. Movies and theatres in neighbouring cities are frequently visited.

Full medical care for each resident is provided through membership in the Workers' Sick Fund. Since membership, even in the older Kvutzot, is still far below retiring age, no problem of old age has yet arisen. Funds, however, are allotted for the support of members' parents, several hundred of whom have come to live in the Kvutzot.

Comprehensive cooperation as practiced in the Kvutza has modified certain aspects of family life. The Kvutza woman enjoys equality in every respect. Marriage has lost its economic implications and changes nothing in the status of the woman. The only change is spatial: the couple moves to live in the same room. Children - the "internal immigration" - are highly desired, but their arrival must often be delayed until the economic conditions warrant the installment of a nursery. During the last weeks of pregnancy, the mother is freed from work. After return from the hospital, the child is assigned to trained nurses. Completely recovered, the mother takes up her duties, her nights undisturbed by care for the child, and her work during the day unhampered by worry over her baby whom she knows to be in trustworthy hands.

The child grows up in the children's house, spatially separated from the parents whose company it enjoys in the relaxed mood of leisure time. The affectionate bond between parents and children appears to be rather strengthened by this arrangement.

Education is progressive and aims at the development of a well rounded socially conscious personality, able and willing to carry on the work of the pioneer parents. The results so far observed are satisfactory: there is practically no desertion to the city among those who grew up in the Kvutza. At the age of 18, the youth is admitted as full fledged member

External Relations.

The Kvutza, in contradistinction to the Hutterites, is anything but isolationist. It maintains close relations with the Jewish Agency and with the General Federation of Jewish Labor or Histadrut. In addition, most Kvutzot belong to one of the three roof-organizations formed from among themselves.

The Jewish Agency, established in 1929, was, until recently, the semi-governmental organ through which Great Britain, the mandate power, dealt with the Jewish settlement in Palestine. The National Fund which procures the land on which practically all Kvutzot settle, and the Foundation Fund which advances the sums necessary for establishment and initial maintenance, are affiliates of the Jewish Agency. Both derive their funds from voluntary contributions of Jews all over the world.

The Kvutza is related to the Histadrut in its capacity of workers' agricultural cooperative. Practically all the Kvutza business is done through the Histadrut's marketing and purchasing cooperatives. The Kvutzot avail themselves also of the health and educational services of the Histadrut.

The three roof-organizations established by the Kvutzot are: (1) the United Group (Kibbutz Hameuhad); (2) the Society of Communal Groups (Hever Hakvutzot), and (3) the All Palestine Group (Kibbutz Arzi). Kvutzot of the same roof-organization have a certain informal understanding about seasonal planning; they share information and experience and, in case of emergency, lend personnel to one another.

Achievements.

After initial hard struggles most of the Kvutzot have become quite prosperous. While in 1937 the total income of the Kvutzot was LP 1.005,000 and the total expenditure LP 1.018.000, leaving thus a deficit of LP 13.000, their income in 1941 was LP 2.257.000, the expenditure 2.068.00 showing thus a profit of LP 189.000.

Beyond securing its own welfare, the Kvutza has been instrumental in raising the standards of the country as a whole. It has been attested that "The Government of Palestine itself uses many of the agricultural methods developed by the Jewish colonists as examples for the improvement of Arab agriculture." Thus the Kvutza has rendered valuable services to Jewish colonization in Palestine. It has broken the ground on which now thrive other types of cooperative settlement, and villages of independent farmers; it has proved an excellent and most economic training school for aspirant farmers; and it has served, by taking in a substantial number of unemployed in times of crisis, as an economic shock absorber.

The Experimental Follow-Up.

As far as Jewish colonization in Palestine is concerned, the experiment which began in 1911 has not come to an end with the establishment of the Kvutza. Although this form of extreme comprehensive cooperation proved, and is still proving, to be satisfactory for many, others have felt discontent with certain of its features.

One of the main reasons for dissatisfaction was the constant intrusion of the collective into the personal life of the individual. To secure privacy, the Cooperative Smallholders' Settlement (Moshav Ovdim) was founded, in 1920. Since then, it has attracted quite a number of settlers; but their number was never so large as of those who preferred the Kvutza. At the last count, in 1941, the number of these settlements was 68, with a membership of some 15,000 as against the more than 108 Kvutzot.

Rural Self-Rehabilitation in Saskatchewan.

Since the first Kvutza was founded, comprehensive cooperation has come into wide use as a device of agricultural reform, particularly in Soviet Russia, Mexico, and, more recently, in Yugoslavia, and, to some degree, in Bulgaria, Poland and Hungary. The voluntary character of the Kolkhoz and of the collective Ejido is, however, not undisputed. We shall omit, therefore, their consideration from this essay.[4]

An indication that the evidently voluntary cooperative community is by no means restricted to the specific conditions of Zionist resettlement comes from Saskatchewan, the second area of our summary consideration. Here, comprehensive cooperation is used as a means of rural self-rehabilitation.

Economic Security.

The main need which prompted cooperative action in Saskatchewan was that of economic security. Geographic, climatic and soil conditions forced the framer in this prairie province into the most competitive kind of agriculture, one crop wheat farming. The bad years from 1929 to 1940, when wheat prices hit rock bottom on the world market, and the fields showed a low yield, drove many farmers into bankruptcy. The Wheat Pool helped to stabilize prices, but there were many who could not be saved through cooperative marketing. Some of them emigrated to the U. S.; others went north, into the wooded area of the province. The difficulties they encountered on their new homesteads forced many of them to accept relief and re-establishment aid, until the war boom in farm products made self-support possible. At this point, the most advanced began to consider action which would prevent the recurrence of distress. Machines, to clear the bush and to break the land, would directly help strengthen the economic basis. But any large scale equipment was beyond the reach of the individual farmer. The machine sharing cooperative offered itself as the natural first step towards self-help.

Four of the incorporated cooperative farms in Saskatchewan are of this type: The Round Hill and the Mount Hope Agricultural Production Cooperatives, in the north-west; the Algrove Cooperative Farm and the Orley Production Cooperative Association, in the north-east. Round Hill, the oldest of these cooperatives, was incorporated, with ten members, in 1943; all others, with a membership of from 5 to 30, in 1945 or 1946. Cultivated area ranges from less than 1,000 to 3,500 acres. The original investment per member amounted to less than $500 at Round Hill. In general, investment per cultivated acre varies from three to five dollars, as compared with from ten to twenty dollars on individual farms in the same area. Pooling of machinery is, so far, the main feature of these farms; but it is considered as preliminary to a more inclusive kind of cooperation. Two other farms in the north, the McIntosh and the Turner Cooperative Farm, have already begun to add other enterprises, such as dairy and poultry, to their cooperative activities.

Social Contacts.

Another need which cannot well be satisfied on the individual farm in Saskatchewan is that of adequate social contacts. Great distances between the farms and poor roads - blocked for days in summer by rain and for months in winter by snow - force the farmer and his family into dreary isolation. Lack of technological, medical, educational, and recreational services offers a serious problem, even for the farmer who is well off.

The Sturgis Farm Cooperative, established in April 1945 in the north-east of the province, was formed by relatively prosperous farmers who, after two years of group study, came to the conclusion that the cooperative community offered the best solution to this problem. This group is interesting because of the high social and educational background of the now

4. They have been treated in this author's *Cooperative Communities at Work*. N. Y. 1945. Dryden Press, and London. 1947. Kegan Paul.

13 members. All had been farmers with fair size farms of their own; one is an M.P. another a delegate to the county council; three of the men and two of the women are college graduates; one a former college instructor. The group operates 17,000 acres of land, with an original investment of $8,000 per member family. Pooling of resources netted through sale of surplus machinery, an immediate saving of $4,000.

Succession on the Farm.

A third basic need is that of fair provision for the younger sons. When the farm is taken over by the oldest brother, the younger ones have only one choice left; to become hired men. Only a few of them can hope to acquire a farm of their own, and this only after years of strenuous effort and self-denial.

One family, at last, found that cooperation offered a fairer arrangement for all concerned. On the Laurel Farm, founded in January 1946 north of Saskatoon, the younger sons start out as full fledged members and co-owners of the cooperative farm which was formed when land and equipment owned by the father, the son-in-law, and the oldest son, were pooled. The group of ten family members was recently joined by a young married couple from the neighborhood, and operates 2,800 acres.

The Veterans.

There is, finally, the need "to do right by the boys who had helped win the war". The veteran who is married has a good chance, with the aid of the Federal Government, to acquire a farm; but he is practically out of luck if he is single.

To solve this problem, the CCF Government, in power in the province since 1944, proposed to organize cooperative farms for the veterans. The first such farm was established, in the spring of 1946, at Matador, in the south-east of the province, with 15 men. The group operates at present 2,600 acres which is less than a third of the area leased to the farm by the Government, on a basis of 480 acres per man. Last year, a second veterans' cooperative farm was added, in the Carrot River area, where according to latest reports, a third one is in the process of formation.

A Favorable Political Climate.

Four basic needs can be discerned, then, as motivating the trend towards cooperative farming in Saskatchewan. They are: the need for economic security; for adequate social contacts; for fair succession on the farm; and for land for the single veterans. In our presentation, we have treated each of these needs separately; in reality, they are of course all interrelated.

The number of members in each of the ten farms is relatively small, just about that of the group which started the first Kvutza. But the farms are growing, steadily though slowly, both in size and in numbers. Although none of them is older than three years, they seem to us to be indicative of a solid trend. In true democratic fashion, they have grown "from the grass roots" and are thriving in the friendly political climate of a helpful and understanding Government.[5]

Conclusion.

The two developments sketched in this paper different as they are in many respects, appear to have several essential things in common. We note that in both instances socio-economic re-organization occurs in response to needs which cannot be satisfied by individuals acting alone; that in resorting to cooperation, both extend the Rochdale Principles to a more comprehensive scope of activities; and that the procedure followed by both is that of a self-started, self-subsisting experiment.

This type of experiment has found, so far, hardly any consideration in sociological literature; a word or two of explanation may not be, therefore, out of order. Greenwood, in his comprehensive survey, distinguishes four main types of sociological experiment: the pure; the uncontrolled; the ex post facto; and the trial-and-error experiment. To these, he adds the "controlled observational study".[6] In all these experiments, the data are handled according to the canon accepted in the physical sciences, i.e., without regard to the meaning which the experimental situation has for the manipulated entities. But it is only insofar as they coordinate with the four dimensions of space and time that social phenomena can exhaustively be comprehended by the methods of

5. For a more detailed description, see the author's: "Cooperative Farming in Saskatchewan". In: Yearbook of Agricultural Cooperation. London, 1947; and: Sociometric Structure of a Veterans Cooperative Land Settlement. Sociometry, No. 15. N.Y. 1947. Beacon House.

6. See: Ernest Greenwood: Experimental Sociology. N.Y. 1945. King's Crown Press Ch. II. pp. 5 ff.

physical science. The case of sociology, it seems to me, rests on its capacity to size up scientifically the fifth dimension of social reality or what, for want of a better word, we might call "meaning". A decisive aspect of any inter-personal configuration lies in the interpretation given it by those who are part of it. No experiment, and no other method of exploration for that matter, can be rightly called sociological if it neglects to take this aspect into consideration.

The procedure which led to the establishment of the Kvutza contains, as we have shown, all the elements of a sociological experiment. It started with the assumption, or "hypothesis", that cooperation could succeed where individual action failed. Each change in the "experimental set-up" was tested operationally and was accepted only after it had been "checked" in terms of group satisfaction, probably as valid a "control" as can be found for this kind of experiment. It is in this sense that we called this procedure that of a self-started, self-subsisting experiment.

At each step taken in the evolution of the Kvutza we have tried to indicate the "meaning" it had for those who took part in it. We could not do the same in the case of the Saskatchewan cooperative farms; partly because of limitations in space, and partly because of their less advanced stage of development. But as far as they have advanced to date, these farms appear to follow, in their own way, the Palestinian precedent. It might be expected that the experience of the original will be matched by that of its successor. Of the two, the Palestine development is by far more advanced, in time and size as well as in achievements. But it would seem to us that the lessons to be learned from the case of Saskatchewan are more directly applicable to some of our own problems. This for the following reasons: These Canadian farmers who are making such auspicious beginning in cooperative farming are in no way different from their U.S. equals. Both the Canadian and the U.S. farmer, are very much alike in their general economic conditions, political system, cultural background, and mental make-up. There is probably only one main difference; of the two, the Canadian is the more hard pressed. Should the need for self-help again arise among us, it can well be assumed that the American farmer will have no difficulty in accepting the solutions offered him in the cooperative actions of his closely related neighbor in the North.

AUTOMATISM AND INDUSTRIAL WORK[1]

by

Georges Friedmann
Conservatoire national des arts et métiers, Paris

Translated by Alfred and Emily Stafford, University of Wyoming

Editor's Note:

With the growing interest in regard to human relations and industry, a translation of an article by Professor Georges Friedmann, of the Conservatoire national des arts et métiers, of Paris, is pertinent at this time. It is of value to Americans to know what is being done in this field in France, for them to become acquainted with the thinking of a Frenchman who has spent many years in careful study and research on the problems of mechanization. The article makes clear that changes in work organizations are by no means at an end.

Dialectics of the Division of Labor.

During the course of the second industrial revolution which dates from the turn of the century and is based on the general use of electric power,[2] the division of labor, following its internal logic, has resulted in ever-increasing specialization. To work becomes more and more specialized, and each operation, thus delimited, is performed by a machine which replaces the hand tool. The role of man in production itself decreases. Choice, preparation, decision tend to be made elsewhere than in the shop. Intelligence seems little by little to disappear from

1. Translated from *"Automatisme et travail industriel"* CAHIERS INTERNATIONAUX DE SOCIOLOGIE, Vol. I, pp. 139-160, Paris, 1946.

2. See Georges Friedmann's study *"La crise du progrès"*, Paris, 1936, chap. I, for more details on the second industrial revolution, which he distinguishes from the first, based on coal and the steam engine.

from production itself and to become concentrated in the conception, design, and performance of the machine, and the Taylor time and motion studies. The production line marks a historic step in this evolution.

But mechanization is not yet complete. The hand of man still intervenes in some operations, such as in placing material in the press, taking it out, and replacing it. This intermediary period abounds in operations that are tiresome to the worker. His work may represent only a half or a quarter of the operation, but it is still a part of it. He is a substitute for the machine in the drudgery which the latter has not yet taken over. Man is far from being everywhere, today, a creator of techniques and a watcher of machines. He is forced to take part in operations empty of any thinking, but which exact, on the other hand, a continual nervous tension and make it more desirable, usually, for him to separate work and thought, to escape in dreaming. At the moment when the last productive motions of the worker will be shifted to pinions, gears, and shafts, complete automatism will begin. It is towards this end that the division of labor seems to tend.

In this sense, the march towards automatism throws light on the whole history of mechanization. For economic reasons, the human motor is less efficient than motors run by sources of natural energy. Once the lines of detailed operations are thought out, and, given situations where we find conditions which make this innovation profitable to management, the new techniques permit joining artificial mechanisms to the human motor. In the first industrial revolution of capitalism, the main source of energy was steam, and the machines were entirely kinematic. Typical was the machine tool driven by means of a system of pulleys and shafts connected by belts in turn driven by the crankshaft of a steam engine. Automatism appears and develops in a period infinitely richer in varied technics, namely, that of the second industrial revolution, which uses the new forms of energy and the most delicate and complex mechanisms as substitutes for the motions and senses of man, (i.e., electrical controls, photo-electric cells, etc.)

It is not exact to say, as it often has been, that mechanization was developed in order to diminish the work of man in production. As a matter of fact, the history of technics shows that in many cases machines were not considered or were temporarily abandoned when hand labor remained more profitable to manufacturers, regardless of the drudgery entailed. The manufacturers who adopted the mule-jenny or the first blast furnaces were certainly not guided by humanitarian motives. But man is sometimes expensive. He tires quickly; his production is limited, finally, by his physiological make-up. Associated with factory legislation which has been slowly enacted as a result of the labor movement and accepted by management for its advantages, machines have often, in fact, reduced human effort. Thus, only the study of the labor market and of economic and technical conditions of production permit our understanding, in each special case, the appearance of automatism. In itself it constitutes a new step in this singular development by which man withdraws little by little from the manual operations of production, ceasing, as the philosopher would say, to be the object of it in order to remain only the subject of it.

Automatism is foreshadowed far back in the history of technics. We can, for example, study its progress on the lathe. The first rudimentary machine-tools with which the worker turned the object itself to shape it were potters' wheels. Today, the turning operation is used only for cutting materials. The earliest illustrations of turning between fixed centers show the worker in a dual role. He is at once the motive power and tool holder. The Egyptian artisan, employing a drill and bow, used only his two hands; the turner, himself, using one hand to move the bow, and the other to guide the tool on the object being fashioned had, often, moreover, to use one of his feet.[3] We may see, then, how important the members of the body were in this mode of production. The whole man is engaged in the productive effort, his body supplying the motive power, the means of transmitting it, and serving as a natural tool.

Later, the division of labor appeared in a form at first rudimentary. The same individual was no longer both motor and operator. At first, one or several workers operated a large bow. Then, finally, by means of a crank and a transmission system the object being shaped was made to move continuously in one direction. The turner, henceforth freed of supplying the motor force, could now assume a standing posture with both hands available for manipulation of the tool. A considerable period of time had to elapse, however, before any important progress was made in the reduction of the muscular effort as applied by man in the operation of turning. This progress was the result of the invention of the tool-holder which seems to have spread through the west-

3. A. P. Usher, *"A History of Mechanical Inventions"*, New York, 1929

ern world toward the end of the 18th century. It permitted the worker to regulate mechanically by means of a mechanism between the hand and the tool the position, pressure, and depth of cut of the tool with reference to the object being turned.

At this point, the role of the operator in turning was still important. His potential skill was freed, so to speak, and was thus pointed up by the technical progress which had relieved him from the heavy work of supplying the motive force and of maintaining the tool against the object. Freed of these functions the operator could develop his initiative and skill to a considerable degree in the art of turning which becomes essentially the manipulation of the tool and removal of the object.

At this, the next stage, in the evolution of turning, the motions of the tool were controlled through a set of mechanisms inserted in the carriage of the lathe. Contemporary technics thus made possible the further elimination of man as an agent in the turning process. These last modifications thus place the process of turning on the road to automatism.[4] Compare, for example, the engine lathe, one of the most common machines of the shops, with the corresponding machines used in mass production. Some of these semi-automatic lathes still carry only one tool, but are operated by levers. The effort of the worker is thereby further simplified. Such is the Boley precision lathe. Others, namely, the multicut lathe, carry several tools. Here it may be pointed out that the lathe seems to have been one of the first machines which included these improvements. The machine-designers wanted to eliminate the inefficiency resulting from the necessity of moving the work from one machine to another for each operation in the turning process. With the engine lathe the moving of the piece from one lathe to the next for each new operation quite often introduces a certain amount of eccentricity (for the axis may be changed in replacing the piece in another lathe). In the precision lathe the piece being turned is fixed during all operations. However, the tool changes take a great deal of time and introduce the risk of error. In the turret lathe, several cutting tools can be mounted on the tool post and can be adjusted and set individually so that each can, in turn, be brought into operation automatically. In this case, technical progress has consisted in the grouping, on a single machine, of several tools which may be presented automatically to the object being fabricated. These types of machines are numerous. Usually each tool has a variable stop which may be set to limit its action. The degree of automatism of these mechanisms is quite variable, from the lever which is moved by the worker's hand and which sets the turret lathe into motion, and thereby the action of each tool, to the setting of the multiple tool holder for an unlimited cycle of operations. "Many of these machines have only a faint relation to the common lathe from which they evolved. Some are automatic for the duration of a cycle corresponding to the production of a piece. Others which present a number of parallel broaches grouped around an exis and with a corresponding number of tool-holders are automatic for an indefinite period."[5]

The complete automatism of the lathe is of practical interest, of course, only in mass production and especially in the manufacture of small items; screws, bolts, nuts, watch parts, etc. At the same time that the intervention of the worker has been eliminated, it has been necessary to increase the production of these delicate and expensive machines in order to make them profitable. Their production has been increased, for example, by a design which makes possible the simultaneous working of several items mounted side by side. At the same time the mode of action of the machines has been so perfected that they may carry various tools thus permitting a whole range of operations such as broaching, boring, drilling, countersinking, threading, sawing, etc. This complex tooling is valuable for the mass production of small electrical parts. It is not uncommon to see high-production automatic turret lathes accomplishing from ten to twenty different operations. Technical progress, by its inherent logic, tends to reconstruct, in these multi-function automatic machines a new form of unity in work on a new plane.

The Three Stages of Automatism.

The relationships between division of labor, manufacture, mass production and automatism now appear more clearly. The division of work, such as it tends to be realized in manufacturing, shattered the unity of the traditional crafts. When Adam Smith described the manufacture of pins in his day, each parcel of work, each task would have been ready for mechanization if economic conditions and the state of the arts had permitted. Once mechanization has begun, the objective becomes that of transferring to machines the energy-consuming heavy tasks formerly effectuated by man. Nonetheless, the hand con-

4. P. Maurer, *"Machines automatiques, mécaniques et électriques"*, Paris, 1934, p. 39.
5. Androuin, *"Le travail des métaux aux machines-outils"*, Paris, 1929, p. 356.

tinues to be important for some functions. Man was first eliminated as a purely motor force. Such was the case in the textile industry. However, in the present stage of development, the worker continues to be an active agent in the processing of the material. The more extensive the division of labor has become in the industrial era, the easier it has been for inventors to realize the kinematic combinations which could be substituted for the natural organs of man, and which point toward automatism. In the shoe industry, for example, the detail operations, such as glazing, cutting the heels, turning and finishing, among others, have been rapidly committed to automatic machines.

Present-day industry presents, diversely distributed according to regions, industries, economic conditions, and financial backing, three kinds of machines which also mark three stages of automatism, among which are the intermediary forms. First of all, there are the so-called "dependent" machines. Their supply of material and their regulation of operation are under the constant surveillance of man. These were the machines introduced into the factories during the first industrial revolution. They continue to be used to the extent in which that revolution presently survives. In the second place, there are the semi-automatic machines, an example of which we have analyzed with the turret lathe. Finally, and as a result of the perfecting of the earlier types of machines, the automatic (independent) machines have evolved. At this point the worker, as an operator, is eliminated. He now has other functions such as watching, controlling and adjusting the machine. The worker can henceforth supervise several machines. In some mills a crew of weavers looks after several hundred automatic looms. The modern chemical industry offers numerous examples of tasks, sometimes delicate, which consist mainly in watching gauges (pressure, temperature, density, etc.). The muscular effort thus becomes insignificant or nil.

The closer one approaches to automatism--without actually attaining it--the more the residue of work remaining to man appears, in itself, devoid of any intellectual or technical interest. There remain only a few very simple constantly repeated operations, the elimination of which is already foreshadowed by the possibility of complete automatism. It would seem that the machine has attracted man in order to compensate for its deficiencies. Then it has dominated him completely and imposed on him its own needs. "Man supplies those functions which are lacking to the machine thus compensating for those imperfections which thwart the machine in the satisfaction of its needs. If it lacks eyes, he sees for it; if it is without legs, he walks for it; and if it needs arms, he pulls, lifts and carries. This is all accomplished by the worker to the rhythm fixed by the machine under its direction and its command."[6]

In the above category may be placed work associated with mass production so common in large industrial enterprises, as, for example, the operation of presses and stamping machines. The workers in this case may be classified as unskilled, semi-skilled, women, and, in France, North-Africans. An examination of this last type of work shows well the advantages of total automatism and the contribution it can make to the humanizing of industry.[7] In non-automatic machines, the worker must supply the machine with each object to be machined. He must adjust himself to the rhythm of the machine. On the other hand, the automatic machine, once supplied with material, has its production assured over a long period. The worker supervises and intervenes only when the supply of material is exhausted. He is no longer constrained to synchronize his movements to the rhythm of the machine which is precisely what brings nervous tension, fatigue and tediousness. The most fatiguing kinds of work appear, then, in those industries in which the process toward automatism has been arrested for such diverse reasons as technical difficulties inherent in automatisation, indifference, persistence of long established methods, poor salaries for semi-skilled labor in certain regions or industries, etc.

From other machines we may be able to understand the type of human effort which will be associated with automatism. As early as 1893, M. d'Ocagne had established the technical principles on which calculating machines are based.[8] From these principles it follows that, if calculating machines reproduce intellectual work, the operator must prepare the work. His manipulations vary according to the operation to be carried out and exact a continuous attention. His nervous system is integrated into automatism. In this case as in the movements of the linotypist or the operation of a telephone switchboard, the human element is reduced to a minimum, but the

6. H. Marot, *"The Creative Impulse in Industry"*, New York, 1918, pp. 4-5.

7. Wyatt and Langdon, *"Industrial Health Research Board"*, Report number 82, London, 1938.

8. M. d'Ocagne, *"Le calcul simplifié par les procédés mécaniques et graphiques"*, Paris, 1893.

responsibility for a cycle of operations inexorably set into motion by automatic mechanisms only demands a sharper attention with its greater fatigue and strain.

Automatism must therefore be considered from several points of view. The worker is freed to the extent that he is relieved from the tedious and in particular from muscular work. On this subject Edgar Atzler has observed that it would be advantageous to automatize as rapidly as possible the heavy operations so that they may cease to be "cortical" in order to become "medulary".[9] A detailed psychological analysis of semi-automatic labor would be valuable in permitting us to determine precisely those kinds of work which still require something more than reflexes, those tasks in which the personality of man is engaged to only a slight degree. These intermediary forms between the traditional crafts and the new labor requirements seem the most difficult, the most refractory to the harmonious development and the equilibrium of the individual. Man is thus half assimilated by mechanization without any compensating benefits.

Mass production is, for certain personality types who are ill-suited for it, in this category of semi-automatic work. It fills some of the gaps in the process of mechanization; man is responsible for operations which, although divided to be accomplished by crews, are still too complex to be reduced to mechanical combinations. In a production system already largely mechanized manual operations must synchronize to the rhythm of the rest of the plant. Mass production was adopted only when the production booms and markets, accompanying the second industrial revolution, required it. But it would not have been technically impossible to establish mass production methods at the beginning of the manufacturing era. Contemporary industry affords numerour examples of very simple arrangements which permit the worker to take immediately the work of the preceding operator and to pass it on to the next one. There is nothing easier, for example, than to pass lots of pins from one worker to another by a system of inclined planes. In the example of the division of labor analyzed with such penetration by Marx, namely, that of the manufacture of a carriage,[10] the introduction of a production line would have been technically possible as early as the end of the 18th century. But it was economically possible only within the frame of rationalization and of mass production. Mass production, in many cases, is like a signal which reveals to us the current deficiencies of techniques in every circumstance where man continues in specialized operations that mechanization cannot yet perform.

The Technical Conditions of Automatization.

Maurer has investigated the technical conditions necessary for the realization of this trend toward automatism and has attempted to define its limits.[11] We shall not dwell here on his attempt to find the law of Spencerian evolution in the march of machines, that is, the passage from a state of homogeneity and deffusion to one of heterogeneity and specialization.[12] What is meant by "Homogeneity" when it is a question of mechanical combinations? In reality, the Spencerian law explains, among other things, the division of labor, but does not take into account the dialectical transformations of the process such as the reciprocal action between the division of labor and machinism. The latter could be realized and employed only from the day when the former had itself been sufficiently developed. But the very imperfection of the first machine tools, capable of only a single operation, has influenced and accentuated the division of labor in its turn. The specialization of the machine exercised this action on the division of labor for a long time, and the two transformations stimulated each other reciprocally until the time when technical progress thus acquired, framed in the capitalist movement of "rationalization", permitted the reconstruction of new unities of work by means of multi-function machines. These are complex transformations which the systematic application of biological laws to the history of technology cannot explain. Such extrapolations or analogies from one level of reality to another are likely to be little more than a play on words.

On the other hand, specific efforts to formulate a definition are not without value. "In general", wrote Maurer, "a machine is a combination of mechanisms, kinematic or non-kinematic, which are associated and combined so as to effect a certain operation.[13] These combinations can either be changed

9. E. Atzler, *"Körper und Arbeit"*, Leipzig, 1927, p. 428.
10. K. Marx, *"Le Capital"*, t. I, Chap. XII.
11. P. Maurer, *"Machinism et automatisme"*, Paris, 1927.
12. *Ibid*, pp. 17 sq.
13. *Ibid*, p. 35.

constantly by man's hand which regulates the action, speed, cut, advance, etc., of the tools, or be fixed in advance and adapted to a definite cycle of operations. In withdrawing from production, man creates these various combinations of mechanisms, assemblies more and more complex and autonomous. The motions thus reserved to man tend to become ever more curtailed. We see now in semi-automatic machines, a transitory form, that the machine is manipulated by very short motions of the operator as in the case of the Boley precision lathe (operated by levers). That is also the case with the so-called automatic telephones, which are in reality semi-automatic. According to Maurer's suggestive expression, there intervenes beyond these human impulsions the "cycle of predetermined and autonomous relations" of the automatic machine. The latter is characterized, precisely, by this autonomous activity which is substituted for the interventions by man's organs. "The rhythm or mobility of the machine must be modified, that is to say, its cycle of predetermined and autonomous relations must be altered according to the external or internal factors or forces which impinge upon it. In order to respond to these conditions, it must possess quick and sensitive receptor mechanisms for predetermined operations. Certain arrangements must direct the impulses received by the receptor mechanisms to the mechanisms of execution. Finally, to balance this complex and skilled assembly there will be other mechanisms functioning as supervisors, controllers, or reflexes which will serve as safety devices".[14]

Let us examine more closely the conditions essential to man's successful elimination of man. The worker commands, regulates, and combines the action of the dependent machines. These interventions are themselves linked to very precise circumstances of production. It is a question of deciding if they are replaceable by mechanisms. To arrive at replacement, a machine designer must catalogue all these circumstances, the judgments which they exact and the impulses by which those judgments are immediately translated into motions by the worker. Then he must determine equivalent mechanical combinations for each of these circumstancial judgments and their related machines. Given the favorable economic conditions already alluded to, the progress of automatization is thus, it seems, limited at each point in history by the complexity of the purely intellectual operations brought into play in the process of industrial productions. It is, also of course, theoretically limited by the existing state of technical progress. These limits are today, thanks to the development of the physico-chemical sciences, considerably widened, thus opening a large field of activity to inventors.[15]

In particular, discoveries in the field of electrical phenomena have considerably assisted the evolution of industrial technics. A cycle of predetermined and autonomous relations in automatic machines requires a much higher degree of flexibility than did the earlier and simpler kinematic mechanisms which are now being more and more outmoded by contemporary automatism. If we look at the history of technics, we notice very early a hydraulic automatism of which Greco-Roman antiquity offers many examples and which Descartes praised in his "Traité de l'homme."[16] Little by little the hydraulic gave place to kinematic automatism. The works of Vaucanson in the 18th century are examples of the latter. Automatism today appears to be electric and even photo-electric. It tends to replace man's nervous system by another system of energy capable of supplying an equivalent impulse at the desired moment. Modern automata choose ingenious intermediaries, often simpler than human organs. In many applications the displacement of manual controls by automatic controls appears theoretically possible.

14. *Ibid*, p. 36.

15. We should mention here, at least, the works of L. Couffignal *"Sur l'analyse mécanique. Application aux machines à calculer et aux calculs de la mécanique céleste"*, Paris, 1938, and the exposition of it which he made in *"L'Homme, la technique et la nature"*, Paris, 1938, pp. 279-291.
From these original and vigorous works let us retain the conception of what M. Couffignal calls the "Abstract mechanical Analysis" by which it is proposed to study the various activities in which man has been or *will be* replaced by machines and to seek the laws of this substitution. In the final analysis, there would thus be possible a preliminary *logical* determination of industrial operations susceptible of being automatized. This condition is necessary but not sufficient since there must be added to this theoretical determination the practical discrimination by the technical possibilities and economic income.

16. Hydraulic automatism was also developed in the Orient. *"Le Traité des Automates"*, by Al Tazari (mussulman School of Painting of Bagdad) preserved at the Library of Saint Sophia, at Constantinople, and copied in the middle of the 14th century, contains numerous illustrated examples.
Texts from Descartes, *"Traité de l'homme"*, ed. Adam-Tannery, t. XI, pp. 130-131.

In effect, that which today impels man most often in the course of industrial work, that which determines his action, is the perception of a difference. "Automatic senses" now record and translate these differences.

In the case of a steam engine, for example, an engineer, perceiving a change in the readings of a monometer or a thermometer, translates his perception of a difference, through manual operations, into a modification of the heat and steam supply and a regulation of the throttle. In the same way an operator may note a difference in readings of a dynamometer scale and then act accordingly. But each of these perceptions of variation might also be used to energize a system of suitable electrically mechanized controls in order to produce the same result. For Example, a difference of pressure in a manometer, instead of resulting in a visual impression in a human operator, might serve to energize an electric circuit. The mercury of a thermometer, having reached a certain level, might close a contact, or the needle of another instrument might intercept a light ray focused on a photo-electric cell. The submarine torpedo of today is, in similar fashion, a sort of automatic machine maintaining itself at a constant level under water. It contains for the purpose a compartment of compressed air which a movable diaphragm separates from the outside water. This diaphragm, sensitive to differences of pressure, controls the depth of the torpedo. In the automatic telephone, electro-magnets activate the cycle of predetermined and autonomous relations in the mechanism, permitting it to choose the free lines at each point in its predetermined cycle of operation independently of any human intervention and to put them to use by an appropriate signal. Similarly, today, much research effort is being applied to the problems of automatically-steered ships and pilotless airplanes.

Progress seems to profit from a wide field of current developments. The principle of perception of differences in automatic arrangements may henceforth be expected to invoke the most diverse senses. Differences between variously colored light rays translate into differences of temperature which, thanks to very delicate thermometers, may be used to activate further automatic systems. Similarly, tone differences automatically caught by multiple resonators can be set in advance to work within predetermined ranges of sensitivity.

Extension of the Phenomenon.

The movement toward automatism has shown a steady growth since the world depression of the 1930, even in those countries with a long and sometimes routinized industrial tradition, like England, and in those, like France, in which great variety in modes of production and inertia on the part of many factory owners, as well as owners' hesitancy at taking risks, often retard modernization of machinery. Depression did not, as is sometimes believed, stop efforts toward rationalization. After completing his statistical studies, Francois Simiand could affirm that these efforts seem greater, on the whole, during periods of depression than in times of prosperity.[17] Current visits to shops, in highly diverse branches of production, give the impression of a penetration which is, on the whole, already quite marked. There is no large scale production where automatism has not already absorbed at least some important operation.

In the modern glass industry, for example, automatism has penetrated all the operations, from fusion at high temperature of sand, soda, and lime to the removal of the finished bottles from the mold. The few manual tasks which remain here and there seem (as in the case of the Rockware Glassworks' enterprises at Middlesex at the time of our visit in 1933) anachronistic; and the workers who do them seem, at a glance, like "stop-gaps" of between cycles of mechanized labor. Such are those who, between two automatic machines, seized the redhot molded bottles with hooks and placed them on a moving belt. Such, also, are those responsible for inspecting and packing, control operations, which, requiring complex judgments, are more difficult to mechanize. The cotton spinning industry adopted automatic mechanisms at an early date. The first alternative looms, characterized by the mule-jenny, consisted of a group of relatively simple mechanisms which left to the spinner the command of all the machine's movements. Soon these machines were replaced by self-acting winders controlled by semi-automatic arrangements. Today, the winders are in their turn being slowly replaced by continuous looms, entirely automatic, which do the twisting and the winding simultaneously. In preparing and carding cotton (especially in combing and drawing), automatic machines, which the worker only feeds and starts, are common today.

In weaving, automatic looms have a considerable production capacity, and, thanks to safety devices

17: F. Simiand, *"Le Salaire, L'Evolution sociale et la monnaie"*, Paris, 1932, t. II, pp. 52, 254, 381 et passim.

which stop the machine at the least accident, can be grouped in large numbers under the surveillance of one worker who is warned of any deviation by the stopping of the loom. Here are some of the principle automatic devices; the shuttle-control which stops the loom when the shuttle does not drive forward; the shuttle-guard which prevents the shuttle from jumping (a frequent cause of serious accidents); the chain-brake which stops the loom in case a link breaks; the thread-brake which trips the disconnect when the thread breaks or the bobbin is empty.

In all light industries, such as the manufacture of garments, gloves, shoes, toys, and brushes, automatic machines have found another particularly favorable economic and technical field of application. In large novelty and toy making enterprises there are now shops completely tooled with automatic machines for cutting, punching, detailing, pumicing, and polishing combs and brushes. The manufacture of cigarettes has been rapidly automatized. As early as 1932, the government cigarette monopoly had adopted a machine which produced eighty-five packs per minute. All the operations, including counting the cigarettes and making and sealing the packages, were effected by automatic mechanisms. The automatizing of painting operations (formerly done by hand by skilled craftsmen) has eliminated work which if often unhealthy. Various machines have been perfected for different industries. In a large oil refinery we have seen a completely automatized shop where each barrel, fixed on a turn-table, moved in turn on a fixed nozzle.

We cite, further, among so many remarkable automatic machines, those adopted by some large refineries. With no intervention or intermediary manipulation by a worker, two machines, forming a group, transform the blocks of molded or sawed sugar into sealed, inspected, and carefully weighed packages. The first breaks the sugar into pieces and assembles packages of around a kilo (or a pound). The second stamps the exact weight and places the covers on the packages. Each of the machines, driven by an electric motor, operates at a rate independent of the other, thus maintaining the greatest flexibility for the group. The industrial production of the whole of the group is twenty-five packages of one kilo a minute or, in eight hours, twelve tons of sugar, broken, packaged and weighed. Three workers suffice to watch this tandem arrangement of machines (two for the crusher, one for the weigher). With the high rate of production of this equipment, its period of amortization may be short.

The domain of automatism, extended by the use of more and more complex applications of energy, goes well beyond that which could have been predicted for a strict utilization of the principles of mechanism. However, economic and financial determinations must not, at any moment, be forgotten if we wish to estimate the practical prospects of the movement in the present industrial order. Under what conditions is it desirable to substitute an automaton for the human senses? If the machine obtained is too expensive with reference to its production and the total sum of the wages it eliminates, it will not offer any financial advantage (for example, the automatizing of machine-tools is at present profitable only in mass production, with the standardization of fabricated pieces and the more and more perfect specialization of the machines). Merely dangerous or laborious jobs even though they can be eliminated by conversion to automatic machines, will not see such machines produced and used in the factory from motives of safety and humanitarian feeling alone.

Theoretically, automatizing human work is always possible if the machine designer has carefully analyzed, in the first place, all the external forces to which the machine must react and if he has conceived mechanisms capable of translating these responses in a predetermined manner. Automatism, in its progress, collides, then, with the complexity of the intellectual operations still required by the kinds of work from which man has not been eliminated. Granted this, is it possible then not to see that automatism constitutes the next step in the development of machine technology? The history of technics and of modern industry both tend in that direction. Furthermore, this movement exists, not only in techniques of production, but also in those of communication, of transport, and of leisure. Man ceases to be an active power in production and becomes more and more a sort of demiurge who decides, gives impetus, superintends.

Previews of Work with Automatism.

As for the human side of production, the progress of automatism could well change profoundly the present problems of labor associated with industrial production. The simple and monotonous functions of the present army of workers who are mere appendages of carefully specialized semi-automatic machines would little by little disappear. In shops tooled with automatic machines a set of new functions would emerge, to be performed by highly qualified workers combining the present skills of supervisors and technicians, capable of supervising

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rows of delicate machines and of meeting any emergency incidental to their operation.

Let us recall that the construction of these machines itself requires a whole gamut of delicate and exacting skills performed by skilled mechanics. Often driven from production shops by semi-automatism, with its attendant semi-skilled jobs, these mechanics will find a compensation in the new functions. This royal road of technological development would lead in the end to the elimination of the semi-skilled worker, and the concentration of "the human element" in the hands of skilled adjuster-builders and supervisors, marters of the new automatic machine. That would bring about the birth of a "new class of artisans".

Thus, automatism, pushed to the extremes of its full expression of all its potentialities, can lead to the humanization of machine industry. Not only does it give rise to new skills and combine with them a new conception of work as a creation and regulation of delicate and precise mechanisms; but also it gives to the worker responsible for the simple task of supervising a group of the new machines the possibility that he can, if he has enough general and technical education, rediscover an industrial function of an intellectual quality distinctly superior to that which is today sufficient for the semi-skilled worker in the semi-automatism of the mass production which precedes full automatism. In spinning, for example, the worker, relieved of petty manual tasks (such as cleaning, replacing the threads, preparing the removal of the bobbins) can become a qualified watcher of a group of machines, can know their structure and their role in the train of operations, can judge and cultivate them. In weaving, old journeymen warpers currently express their satisfaction at working on machines equipped with an automatic disconnecting device which in case of a break in the thread, saves them from being obliged, as formerly, to seek it on the rolling drum, sometimes as much as a dozen meters distant. Automatism frees them (according to the term we have several times heard them use) from a "subjection" to the machine and permits them to turn their attention towards the essential aspects of their work. Without doubt, supervisory work can be tiring, for although muscular work may be eliminated, watchful tending imposes, in varying degrees, a nervous tension which industrial psychology is just beginning to investigate. But here we have considerable progress in this: the worker ceases to play the role of an appendage of the machine, bent to its rhythem. His new functions as a watchful controller can be intelligent functions, into which professional interest can again be infused.

Such are the conclusions to be drawn from the psychological and technical analyses of automatism. But these are theoretical conclusions. Their practical value is already put on trial by the persistance of unemployment. Theories on the displacement of labor, like Ford's according to which the workers "displaced" from one industry by technical progress can find work in a new occupations have been conclusively disproved by facts. Under the present conditions of industry (even when it "benefits" from the boom of armament programs), technical progress means not "displacement" of trade, but unemployment for millions of young and able-bodied men. The economic benefits of automatism appear to be inseparable from a social order in which workers working fewer hours, would, nonetheless, enjoy the right to ply the trade (or trades) for which they are best fitted and to consume the products therefrom according to their needs.

A MATHEMATICAL MODEL FOR GROUP STRUCTURES

by

Alex Bavelas
Massachusetts Institute of Technology

INTRODUCTION

Many kinds of theories have been developed to explain human behavior. They may be classified in many ways - in terms of outstanding men, of schools of psychology, in terms of the emphasis placed upon certain concepts or areas of study. A way of classifying which is useful for the purpose of this paper is one which differentiates between a) theories which explain human behavior as a function of factors which may be coexistent but independent of each other, and b) theories which explain human behavior as a function of groups of factors constituting a continuously interacting field.

At the time of the first world war psychologists in Germany were splitting roughly into these two camps: One group followed the path of breaking down the person and the situation into elements and attempting to explain behavior in terms of simple causal relationships. The other group attempted to explain behavior as a function of groups of factors constituting a dynamic whole - the psychological field. This field consisted essentially of the person himself and his environment as he saw it. In these terms, the problem was no longer conceived as one of relationships between isolated elements, but one of dynamic interplay of all the factors of the situation.

At this time Kurt Lewin began to formulate a method of analysis of psychological situations which rested upon their restatement in mathematical terms: geometry for the expression of the positional relationships between parts of the life space, and vectors for the expression of strength, direction, and point of application of psychological forces. The use of geometry was natural in a psychological approach which insisted upon a world "as the person himself sees it", since human beings tend to picture the contextual field as existing in a "space" around them. Also, the geometric approach offered a convenient means for diagramatic representation of many psychological situations.[1] The most important and, in a sense, the only reason for the use of geometry lay in the fact that the assumption of groups of interrelated factors implied the existence of a mathematical space and some means of handling it was necessary. The task of representing the relationships between groups of psychological data laid certain requirements upon the type of geometry that could be used. It had, in the first place, to be a geometry that did not rest upon a groundwork of assumptions impossible to satisfy. Also, in order to be immediately useful, it had to be a geometry that pre-supposed no greater possibilities of measurement and definition than were present in psychology at the time.

A sufficiently generalized and non-metric geometry was found in topology. Certain fundamental notions from topology - "connectedness", "region", "boundary", - showed promise in handling spatial relationships in psychology. These ideas were borrowed and put to use although, for the most part, the assumptions underlying them could not be related to psychology. That these concepts from topology proved useful is beyond question if one may judge from the experimental settings which they stimulated and made possible to formulate. Lewin and his students pioneered in fields previously considered too difficult to approach experimentally.[2]

1. Actually, Lewin never intended to use geometry as a means for producing diagrams or illustrations. His geometrical representations were not analogies to be dismissed whenever their implications became inconvenient. They were intended to be mathematical statements of relationships: not statements of "what the situation is like", but statements of "what the situation is".

2. Barker, R., Dembo, T., and Lewin, K., Frustration and regression: An experiment with young children, *Univ. Ia. Stud. Child Welf.*, 1941, 18.
Dembo, T., Der Arger als dynamisches Problem, *Psychol. Forsch.*, 1931, 15, 1-44.
Kounin, Jacob S. Experimental Studies in Rigidity, *Character and Personality*, 1941, 9, 273-282.
Lewin, K., A Dynamic Theory of Personality, New York, McGraw-Hill, 1935.
-----, Principles of Topological Psychology, New York McGraw-Hill, 1936.
Lippitt, R., An analysis of group reaction to three types of experimentally created social climate, Iowa City, Univ. of Iowa, Ph.D. Thesis, 1940.
Mackinnon, Donald W., A Topological Analysis of Anxiety, *Character and Personality*, 1944, 12, 163-176.
Mahler, V., Ersatzhandlungen verschiedenen Reallitatsgrades, *Psychol. Forsch.*, 1933, 18, 26-89.

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Concepts borrowed out of their context, however, useful though they may be in specific instances of application, rarely yield full value until they are related to each other in some systematic way. The coordination of the formal body of topological geometry with psychological concepts seemed hopeless. What seemed possible was the definition of a geometry which retained the demonstrated advantages of the concepts borrowed from topology, and which seemed suitable as a system to the uses of psychological analysis. Lewin attempted this task by introducing a geometry which he called "hodology." In hodology, primarily designed to treat problems of distance and direction, a basic assumption is that between any two parts of a whole there can be distinguished a "shortest path."

> "In Euclidian space, both distance and direction refer to a connection between two points. From the point of view of topology, this connection is to be considered a 'path' from a to b. There are of course many paths possible between a and b. One of these possible paths is distinguished as the shortest path between a and b..... Since topology does not know differences of size, one cannot use shortness as a general principle for such a selection. It might be possible to substitute for the concept 'shortest path' the idea of the minimum number of regions which might be crossed by a path from a to b. However, we shall not confine ourselves to this one method of selecting a distinguished path from the possible ones."[3]

From this idea of "shortest path" Lewin develops an analytical approach to the properties of wholes. In this paper, he points to the importance of the specific pattern that cells in a whole may take, and he introduces certain concepts regarding regions of special properties in such patterns. Assuming "natural wholes where all boundaries have the same strength" he distinguishes regions in the structure from which a change would spread most quickly to all other parts, and regions from which such spreading would take longest to cover the entire structure. Also, he distinguishes areas in the structure most and least susceptible to changes "on the outside." Lewin points out, also, that these concepts are relevant to both problems of cognitive structure - the organization of mental materials - and problems of group structure - the organization of individuals in social groups.

To go back to the definition of "shortest path", upon which all of the preceding discussion is based, we find that Lewin indicates several possible definitions:

> "The property which makes one path between two regions of the life space outstanding (the 'shortest path') seems to vary considerably with the situation. Sometimes the fastest connection is outstanding; at other times it is the cheapest connection, or the most pleasant, or the least dangerous. So, all that we would like to assume is that there should be, in the given case, one outstanding path from a to b."[4]

The criteria "most pleasant" or "least dangerous" introduce dynamic factors in the problem of defining a shortest path. The criterion "minimal regions to be crossed by a path from a to b", however, is a purely positional one. It seems that only upon the latter type of criterion can one develop mathematical statements of distance and direction as functions of the number and position of the parts in the whole. In this paper, the "minimal regions" criterion for the distinguishing of shortest paths is accepted and an attempt is made to explore in a limited way the consequences of such an assumption. Also, an attempt is made to make changes in or additions to accepted definitions which might permit a more flexible use of concepts developed therefrom. Such changes are not "arbitrary" but are made with an eye to problems in psychology which might thus be handled more easily. In some cases changes which would make certain problems more amenable to mathematization have been avoided because of the complications they introduce in the initial formulation of concepts. A case in point is that of the transitiveness of the "touching" relationship between regions or cells. One of the assumptions made below is that if cell A_1 is said to be touching cell A_2, then cell A_2 may be said to be touching cell A_1." This assumption was made in order to secure certain advantages which will be apparent in the material that follows. But other advantages were foregone. Under the condition of the assumption as stated, a chain of cells may be regarded as a path along which a change of state might spread stepwise from cell to cell - from any cell to any neighboring cell. If one thinks of the chain of cells as representing a sequence of stages through which a person might pass, then one must conclude that the sequence of stages is reversible at any point - a fact not always or often true in human experience.

3. Lewin, Kurt, The Conceptual Representation and the Measurement of Psychological Forces", *Contributions to Psychological Theory*, I, Duke University Press, 1938, p. 25.

4. *Ibid*, p. 25.

If the assumption of transitivity were not made, or explicitly rejected, then it would be mathematically possible to describe chains of cells or paths with very different properties of connectedness. Our hypothetical person might in such a case pass from cell A to B to C but not be able to retrace his steps. The path might be irreversible entirely or in part.

These concepts of pattern and communication are the heart of this paper. They are developed with the deliberate purpose of application to psychological situations. Although no rigid coordination of these ideas with psychological or social situations is attempted, general areas within which application might be fruitful are suggested. For instance, in the realm of social groups, there would seem to be two outstanding aspects of communication deserving attention: that of communication between individuals (or between groups), and that of communication between ideas and attitudes. The spread of rumor is a good example of the close relationship between these aspects. While the rapidity, direction, and extent of the spread depends partly upon the patterns of connection between individuals and groups, they also depend - especially with respect to the growth and bias of the rumor, and the readiness to hear and transmit - upon the connection of the content of the rumor with other ideas and attitudes.

BASIC ASSUMPTION

1. The space being dealt with consists of collections of cells.
2. A cell is equivalent to a point or position in the space.
3. A given cell may or may not be touching another cell.
4. If a cell A_1 is touching another cell A_2, then cell A_2 is said to be touching cell A_1.
5. A cell cannot touch itself.

DEFINITIONS

1. Boundary of a cell: the boundary of a cell A consists of all cells touching A.
2. Region: a region is any class or collection of cells
3. Open cell: cell A is open relative to region g if the boundary of A is not contained in g.
4. Closed cell: cell A is closed relative to region g if the boundary of A is contained in g.
5. Boundary of a region: the boundary of the region g is the class of all cells not in g and touching at least one cell in g.
6. Chain: cells $A_1, A_2, \ldots\ldots, A_n$ are said to form a chain if A_1 is touching A_2, A_2 is touching A_3, $\ldots\ldots, A_{n-1}$ is touching A_n. A_n may or may not be equivalent to A_1.
   a) Simple chain: cells $A_1, A_2, \ldots\ldots, A_n$ are said to form a simple chain if A_1 touches cell A_2 and no other cell, if A_2 touches A_1 and A_3 and no other cell, if A_3 touches A_2 and A_4 and no other cell, etc., ...and cell A_n touches cell A_{n-1} and either does or does not touch cell A_1.
7. Length of a chain: the length of a chain is equal to the number of cells contained in the chain less one.
8. Structure: a region g is said to be a structure if for any pair of cell A_1, A_2 contained in g, there exists a chain contained in g and connecting A_1 and A_2.
9. Distance between two cells: the distance between any two cells $A_1, A_2 (\overline{A_1 A_2})$ in a structure w is the minimum length chain contained in w and connecting A_1 and A_2.
10. Distance between a cell and a region: when cell A and region g are both included in w, and when A is not in g two distances are distinguished.
    a) Maximum distance: the longest distance of all distances from A to every cell in g.
    b) Minimum distance: the shortest of all distances from cell A to any cell in g.
11. The outermost region of a structure: the outermost region of a structure is the class of all cells which are open relative to the structure.
12. The innermost region of a structure: the innermost region of a structure is the class of all cells with the largest minimum distance from the outermost region of the structure.
13. The largest of the maximum distances between the outermost and innermost regions of a structure is denoted by the letter r.
14. The largest of all distances between a cell A_1 and any other cell in the structure is denoted by p.
15. The diameter of a structure: the diameter of a structure (d) is equal to the largest p that can be found in the structure.
16. The central region of a structure: the central region of a structure is the class of all cells with the smallest p to be found in the structure.
17. The peripheral region of a structure: the peripheral region of a structure is the class of all cells having the greatest maximum distance from the central region. This distance will be denoted as c.

A DISCUSSION OF THE DISTANCES d, c, and r.

A Method of Illustration.

In a discussion of patterns of communication within a structure, three structural distances are distinguished: d, c, and r (see Definitions 13,14, & 17). Although not strictly necessary, and often undesirable, some kind of picture of a structure is helpful in illustrating certain relationships between these distances. The pictures will be constructed in the following way: a structure of three cells all of which touch each other would be shown as in Figure 1.

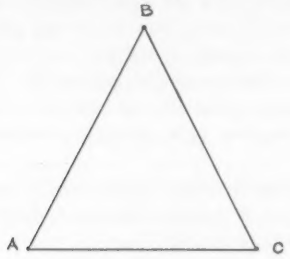


Figure 1

If in this structure cell A was an open cell (see Definition 3), the structure would be shown as in Figure 2.

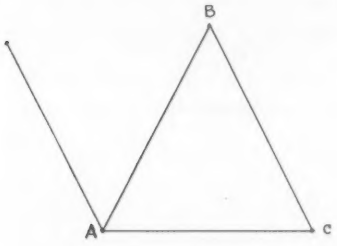


Figure 2

The picture shown in Figure 3 would mean

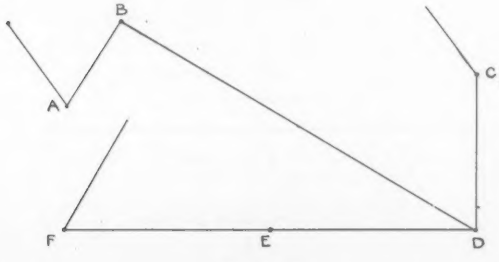


Figure 3

1) That A, C, F were open cells and that B, D, E were closed cells; 2) That A (with respect to this structure) touched only B, and F touched only E; that B touched A and D, D touched B, C, and E, and E touched D and F.

The reason for this change from the kind of pictures used by Lewin is that certain types of structures are very difficult or impossible to draw in that manner. For instance, it is impossible to represent, Lewin-wise, a structure in which A touches B, B touches C, and A and C are open cells and B is closed. (see Figure 4)

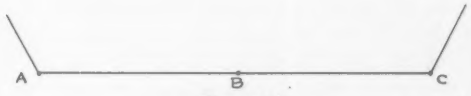
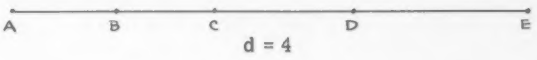


Figure 4

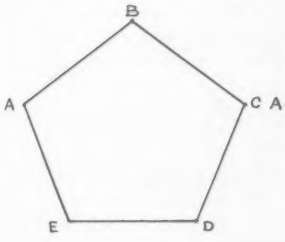
The distance d (Definition 14: The largest of all distances between a cell A_1 and any other cell in the structure is denoted by p; Definition 15: The diameter of a structure (d) is equal to the largest p that can be found in the structure.)

The way in which the distance d may vary in a structure with a constant number of cells can be shown by the use of several pictures.



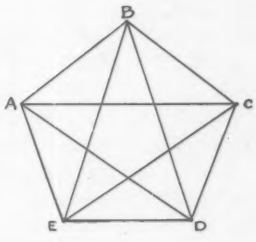
d = 4

Figure 5a



d = 2

Figure 5b



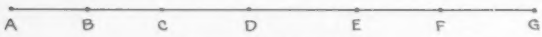
d = 1

Figure 5c

It may be seen from the foregoing illustrations that the limits of the distance d may be expressed in terms of n (the number of cells in the structure). The value of d will be at its minimum when the longest distance which may be found between any two cells is equal to n-(n-1) or simply 1,

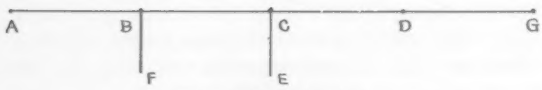
as in Figure 5c. The value of d will be at a maximum when the longest distance to be found between any two cells is equal to n-1 - which means that the structure will take the form of a simple chain in which the first cell does not touch the last one. The distance c (Definition 17:) (The peripheral region of a structure is the class of all cells having the greatest maximum distance from the central region. This distance will be denoted as c.)

The way in which the distance c may vary in a structure with a constant number of cells is shown in the following pictures.



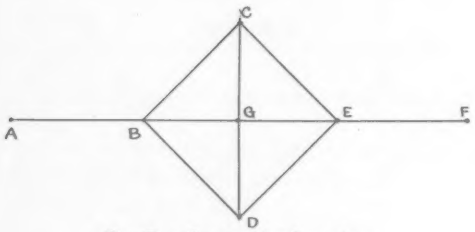
D = central region
c = 3

Figure 6a



C = central region
c = 2

Figure 6b



C + D + G = central region
c = 2

Figure 6c

In Figure 6c the peripheral region (see Definition 16) would consist of cells A and F. Lewin defines the peripheral region of a structure as all cells A for which a cell B may be found so that the shortest distance from A to B is equal to d. In some cases, such as that shown in Figure 6c, both definitions distinguish the same region. In other cases, such as that shown in Figure 6d, the regions distinquished are different.

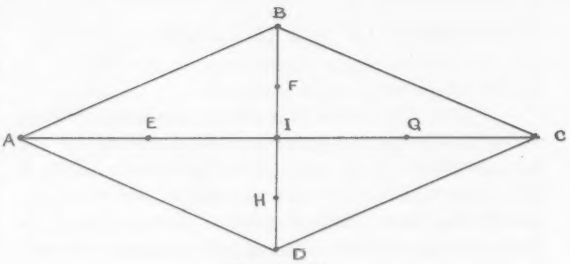
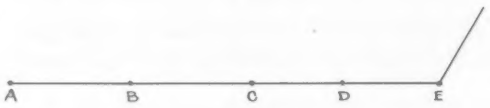


Figure 6d

According to Lewin's definition the peripheral region consists of cells A,B,C,D,E,F,G,H. According to the definition in this paper the peripheral region consists of cells A,B,C,D.

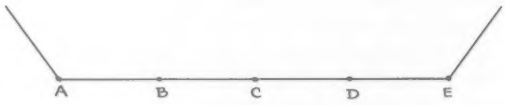
The distance r (Definition 13: The largest of the maximum distances between the outermost and innermost regions of a structure is denoted by the letter r.)

The way in which the distance r may vary in a structure with a constant number of cells is shown in the following pictures.



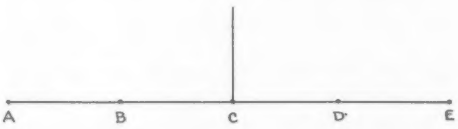
A = innermost region
r = 4

Figure 7a



C = innermost region
r = 2

Figure 7b



A + E = innermost region
r = 2

Figure 7c

In addition to showing how the distance c may vary, Figures 7a, 7b, 7c illustrate some of the properties of a region as they have been defined (see Definition 2). In Figure 7c, for instance, the region distinguished as innermost consists of two non-connected cells as far apart as it is possible for them to be.

The Limits of the Values That c and r may Assume.

The limits of the values that c and r may assume can be expressed in terms of d in the following way.

$$d = c = d/2^{(5)} \qquad d = r = d/2$$

In other words, the limits of the values that c and r may assume are d at one extreme and 1/2 d at the other.

In order to give a proof of these two statements, it is necessary to state a general principle with respect to distances within structures. The principle is that given three cells, A, B, and C in a structure, $\overline{A\,B}$ (the distance A to B, see Definitions 6, 6a, 8) will be equal to or less than $\overline{B\,C}$ plus $\overline{C\,A}$. Proof of this general principle may be developed from the assumptions and definitions:

1) If cell C is contained in the chain $\overline{AB}$, then $\overline{AC} + \overline{CB} = \overline{AB}$.

2) If the cell C is not contained in the chain $\overline{AB}$, then the chain $\overline{ACB}$ is by definition equal to or longer than the chain $\overline{AB}$.

3) Therefore, $\overline{AB} \leq \overline{AC} + \overline{CB}$

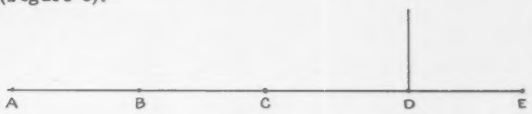
Returning to the question of the limits of c and r in terms of d.

1) Let A be a cell in the central region.
2) Let $\overline{CB} = d$.
3) $\overline{AB} + \overline{AC} \leq 2c$.
4) $\overline{AB} + \overline{AC} \geq d$.
5) Therefore, $2c \geq d$
or $d \geq c \geq d/2$.

And in the same way with respect to r.

1) Let A be a cell in the innermost region.
2) Let $\overline{CB} = d$.
3) $\overline{CA} + \overline{AB} \leq d$.
4) $\overline{CA} + \overline{AB} \geq d$.
5) Therefore, $2r \geq d$.
or $d \geq r \geq d/2$.

Although c and r have the same limits, they do not vary in the same way. Although formal proof of this has not been worked out, structures may be drawn in which c and r do not have the same values. (Figure 8).



$d = 4$ $\qquad c = 2$ $\qquad r = 3$

Figure 8

A glance at Figures 5a,b,c, and 6a,b,c, is sufficient to show that in a structure of n cells the way that d and c will vary within their limits depends upon the number and pattern of interconnections between the cells. This problem was approached in two ways, and although the objective of finding the function along which d and c vary was not attained, the results are interesting enough to be stated.

The Limits of si_x[6] for a Structure of n Cells.

1) In a structure in which every cell touches every other cell $i_x = n-1$ and $si_x = n(n-1)$.

2) In a structure in which each cell has the fewest possible cells touching it, the structure will take the form of a simple chain in which cell A_1 does not touch cell A_n.

3) Therefore $i_{A_1} = 1, i_{A_2} = 2, i_{A_3} = 2, \ldots\ldots\ldots, i_{A_{n-1}} = 2, i_{A_n} = 1$.

4) Therefore $si_x = 2(n-1)$.

5) Therefore, we may say that for a structure of n cells the value of si_x will vary from $n(n-1)$ to $2(n-1)$, the range of variation being $n(n-1)-2(n-1) = (n-1)(n-2)$.

The Limits of $\sum se_{xy}$[7] for a Structure of n Cells.

1) In a structure in which every cell touches every other cell, $se_{A1x} = n-1$ and $\sum se_{xy} = n(n-1)$.

2) In a structure in which each cell touches as few other cells as possible, the structure will take the form of a simple chain in which cell A_1 does not touch A_n.

3) Therefore,

$se_{A1x} = 1 + 2 + 3 + \ldots\ldots + n-1$, and

5. In reading the value of d/2, read fractions as the next higher integer. The quantity d/2 refers to a distance in a structure and distances are so defined that a fractional distance has no meaning.

6. i_A = the number of cells touching cell A.
si_x = the sum of i for every cell in the structure--that is, $i_{A_1} + i_{A_2} + i_{A_3} + \ldots\ldots + i_{A_n}$.

7. $e_{A_1A_2} = \overline{A_1A_2}$; se_{A_1x} = the sum of all distances between cell A_1 and every other cell in the structure; $\sum se_{xy}$ = the sums of all distances between all pairs of cells in the structure.

$se_{A_{2x}} = 1 + 1 + 2 + \ldots\ldots + n-2$, etc., to

.

.

.

.

$se_{A_{1x}} = n-1 + \ldots\ldots\ldots + 2 + 1.$

4) $se_{A_{1x}} = \frac{n(n-1)}{2}$

$se_{A_{2x}} = \frac{(n-1)\ (n-2)}{2} + \frac{n-(n-2)\ n-(n-1)}{2}$

$seA_{3x} = \frac{(n-2)\ (n-3)}{2} + \frac{n-(n-3)\ n-(n-2)}{2}$

.

.

.

.

$se_{A_{n-2}x} = \frac{n-(n-3)\ n-(n-2)}{2} + \frac{(n-2)(n-3)}{2}$

$se_{A_{n-1}x} = \frac{n-(n-2)\ n-(n-1)}{2} + \frac{(n-1)(n-2)}{2}$

$se_{A_n x} = \frac{n(n-1)}{2}$

5) Therefore $\sum se_{xy}$ may be expressed as $n(n-1) + (n-1)(n-2) + (n-2)(n-3) + \ldots\ldots + n-(n-1)\ (n-n)$ or simply

$$\frac{n(n^2-1)}{3} \quad (8)$$

6) Therefore, the range of values for $\sum se_{xy}$ in a structure of n cells will be

$$\frac{n(n^2-1)}{3} - n(n-1) = \frac{n(n-1)(n-2)}{3} \quad (9)$$

Distances d,c,r, and the Spread of Change in a Structure.

One way of studying the communication pattern of a structure is to assume a change of state as occurring in some cell and spreading by contact throughout the structure. Let us assume that at t^0 a change of state occurs in cell X_0, and that at t^1 the change has spread[10] to all cells X_1 which touch cell X_0, and that at t^2 the change has spread to all cells X_2 each of which touches at least one cell of the class of cells designated as X_1. If we assume further that the time intervals t^1-t^0, t^2-t^1, t^3-t^2, etc., are constant, we may describe some aspects of the communication pattern of a structure in terms of the time it takes a change to spread from place to place.

If we consider a simple chain in which cell A touches B, B touches C, C touches D, etc., and assume a change of state as originating in cell A, it is clear that the change will spread at the rate of one cell per time unit "t". If the change of state is assumed to be in cell A at time t^0, then at time t^1 the changed state will be in both cells A and B; in time t^2 it will be in the three cells A, B, and C; and at time t^n the change will have spread to the n^{th} cell. If, instead of a simple chain, we consider a structure such as that shown in Figure 8a with a change originating in cell A, the pattern of spread will be different.

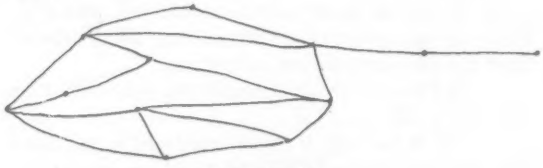


Figure 8a

Although the pattern of spread in a particular structure will be specific to that structure, it is possible to make certain general statements with respect to spread through time on the basis of some of the definitions and derivations made above:

1) A change of state not originating within a structure will start its spread within the structure from one or more of the cells comprising the outer region. Since the largest of the maximum distances between the outermost and innermost regions is equal to $\underline{r}$ (Definition 12), the t^n required for a change or-

8. Let $\phi = n(n-1) + (n-1)(n-2) + \ldots\ldots\ldots + n-(n-1)\ (n-n)$

Then $\phi = \sum_{J=1}^{J=n} J(J-1) = \sum_{J=1}^{J=n} J^2 - \sum_{J=1}^{J=n} J$

$\sum_{J=1}^{J=n} J^2 = 1^2 + 2^2 + 3^2 + \ldots\ldots\ldots + n^2 = \frac{n(n+1)(2n+1)}{6}$ $\qquad \sum_{J=1}^{J=n} J = 1 + 2 + 3 + \ldots\ldots\ldots + n = \frac{n(n+1)}{2}$

$\phi = \frac{n(n+1)(2n+1)}{6} - \frac{n(n+1)}{2} \qquad \phi = \frac{4n^3-4n}{12} = \frac{n}{3}(n^2-1) = \frac{n(n^2-1)}{3}$

9. Notice that the range of Σse_{xy} is $\frac{n}{3}$ times the range of si_x.

10. We will assume in this discussion that the change of state may spread indefinitely without diminution or increase.

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iginating outside the structure to spread to the innermost region of the structure will be equal to $t^{\underline{r}}$. The value $\underline{r}$, however, was shown to vary with respect to $\underline{d}$: $\underline{d} = \underline{r} = \underline{d}/2$. Therefore, the t values necessary for a change to spread from the outermost to the innermost region under the conditions stated above will range from $t^{\underline{d}}$ to $t^{\underline{d}/2}$.

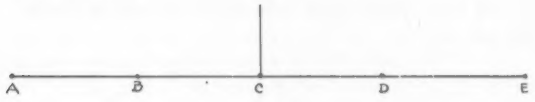
2) A change originating in the innermost region of a structure, by the same reasoning as in 1) above, will require from $t^{\underline{d}}$ to $t^{\underline{d}/2}$ to spread to the outermost region of the structure.

3) A change originating in the most central region, will by definition require $t^{\underline{c}}$ to cover the entire structure. As in the case of $t^{\underline{r}}$, the limits of $t^{\underline{c}}$ are also $t^{\underline{d}}$ to $t^{\underline{d}/2}$. Since, however, $\underline{c}$ is defined in terms of the smallest $\underline{p}$ (Definition 14), $t^{\underline{c}}$ will be equal to or less than $t^{\underline{r}}$.

In summation, one may say that whatever the structure a) a change may not spread throughout a structure in less than $t^{\underline{d}/2}$, b) the smallest possible t for complete spread throughout a structure will be obtained if the spread starts in the central region.

Possible Applications of Some of the Concepts Above to Social Groups.

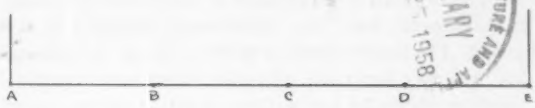
A study recently completed of a national minority organization indicated that the sub-group to which the organization as a whole was most responsive was also the sub-group in closest touch with the non-minority and anti-that-minority environment. Is this an example of a region of a social group which is at the same time the most central and the most outer region? What difference would it make to the life of this organization if its most central sub-group were also its most inner region? The pictures that follow show some of the variations that are theoretically possible.



A + E = innermost and peripheral region
$\overline{AE} = \underline{d}$ C = outer and central region

Figure 9

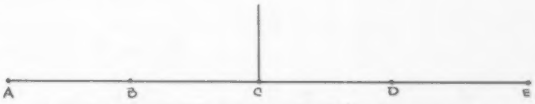
In Figure 9 we see a situation similar in some respects to the one mentioned above. The central region is also the outer region, and the innermost region is also the peripheral region. The innermost region is in two parts as widely separated as is possible.



C = innermost and central region
A + E = outermost and peripheral region
$\overline{AE} = \underline{d}$

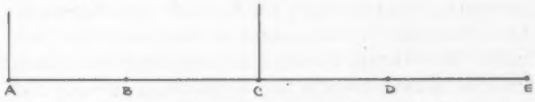
Figure 10

In Figure 10 we see a structure which appears in a sense to be "opposite" that shown in Figure 9. The central region is now furthest from the outside. The region in contact with the "outside" is now an unconnexted region.



C + D = central region and is partly outermost
A + F = peripheral region
F = most inner region

Figure 11



A + E = peripheral region and partly outer
A + C = outermost region
C = central region
E = innermost region

Figure 12

An interesting industrial situation about which the writer was told serves to illustrate a possible meaning of the kind of analysis of structures shown in Figures 9, 10, 11, 12. A group of women employed by a garment factory in a large city and working alongside each other constituted an informal work group. In addition to the fact that they were paid on the basis of their combined production, another circumstance tended to make this group a close social structure: all spoke Italian and only one of the women could speak English at all. Relations between this group and the management of the company regarding hours, wages, working conditions took place through the single English speaking member (this in

spite of the fact that the plant was unionized). Clearly, this woman, with respect to communication with management, was the "outermost" member of the group. The inner structure of the group is not known, but one may speculate as to the effect upon communication within the group of the position she occupied within it.

If, as well as being the outermost member, she were also the most central, the group might be represented as in Figure 9. It is difficult to imagine that the English speaking member would be other than central with respect to communication which had of necessity to pass through her, although under certain conditions such a pattern might well exist. In Figure 12a the English speaking member (E) is shown in a noncentral position.

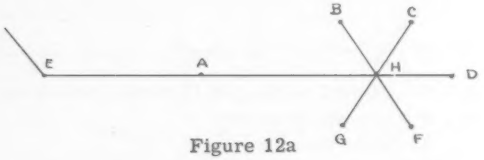


Figure 12a

It is interesting in passing to point out the importance of the position of the English speaking member with respect to the group's perception of the "outside." Even though the outermost region of a structure may be barred from policy formulation, it may still exercise a great effect upon policy decisions. To the extent that policy decisions are based upon information, as to the state of affairs "outside," withholding information, coloring or distorting it in transmission, or in other ways misrepresenting the state of the outside will fundamentally affect these decisions. In a sense, the "perceptual adequacy," loyalty, and morale of the outermost region of a group structures is crucial in maintaining optimum relations with the "outside."

While it is true that the structures under discussion are defined under assumptions which make their strict coordination with industrial or other hierarchical organizations impossible, they do provide a basis for the comparison of structural properties per se of certain types of organizations. There are some questions that can be answered quite specifically. For instance, in an organization of a given type, what is the maximum distance that there will be between any two individuals in it? Will this distance depend upon the number of people in the organization? the number of subordinates under each superior? the number of levels in the organization? the communication possibilities between subordinates? One might ask a different type of question: in a given organization where will the region of greatest centrality lie? Who will be in it? who will be most peripheral?

Some of the answers to these questions can be given. One may begin by specifying three types of structures for comparison.

1) an organization in which a subordinate communicates only with his superior and with his subordinates (Figure 13)

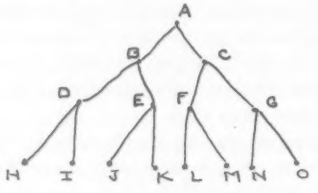


Figure 13

2) an organization in which a subordinate communicates with his superior, the other subordinates of his superior, and his own subordinates (Figure 14)

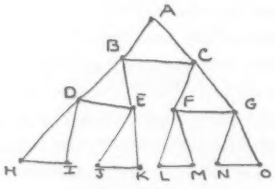


Figure 14

3) an organization in which a subordinate communicates with his superior, all subordinates on his own level, and with his own subordinates (Figure 15)

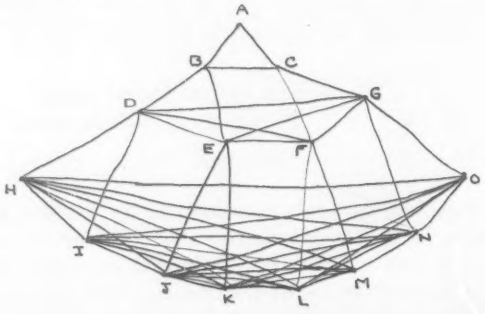


Figure 15

In these structures, as they are defined, the significant variable with respect to the values d and c is the number of levels rather than the number of cells. In Figure 13, for example, it is apparent on inspection that it doesn't matter how many subordinates each superior has connected to him; the d and c values will remain constant as long as the number of levels remains constant. The same thing is true of the structures shown in Figure 14 and Figure 15.

It would seem desirable, therefore, to express the d and c values in terms of the number of levels (L). The numerical values for d and c are shown in the tables that follow (Figure 16 and 16a)

Structure type	No. of cells	No. of levels	d	c
1 (Figure 13)	15	4	6	3
2 (Figure 14)	15	4	5	3
3 (Figure 15)	15	4	3	2

Figure 16

Structure Type	d in terms of L
1 (Figure 13)	2(L-1)
2 (Figure 14)	2(L-3/2)
3 (Figure 15)	L-1

Figure 16a

Looking at the structure shown in Figure 13, it is plain that the longest chain is that containing the cells H D B A C G O. it is also evident that the longest chain in any structure of this type will be the one going from the cells occupying the positions that cells H and O, or I and N, or J and M, etc., occupy relative to the entire structure. The length of the longest chain will always equal 2(L-1).

In the structure shown in Figure 14, the situation is the same except that in the chain H D B A C G O cell A may be omitted, due to the connection between cells B and C. Therefore, in structures of this type the longest chain will be equal to 2L-3.

In the structure shown in Figure 15, by the same process of reasoning, the longest chain will be L-1.

It appears, therefore, that the difference in d between the first two structures becomes insignificant as the number of levels increases, but that the difference between the d of the third type and the other two becomes increasingly great. For example, in a structure of ten levels the structures would show these d distances (Figure 17).

Structure Type	No. of levels	d
1 (Figure 13)	10	18
2 (Figure 14)	10	17
3 (Figure 15)	10	9

Figure 17

If we compare these structures with respect to the distance c, it is helpful again to express c in terms of the number of levels (Figure 18).

Structure Type	c in Terms of L
1 (Figure 13)	L-1
2 (Figure 14)	L-1
3 (Figure 15)	L/2[11]

Figure 18

In a structure of ten levels the c values would be as follows (Figure 19).

Structure Type	No. of Levels	c
1 (Figure 13)	10	9
2 (Figure 14)	10	9
3 (Figure 15)	10	5

Figure 19

Another way to compare these structures is that of the location of the central region. In the structure of the first type (Figure 13), the central region consists of the cell A. In the structure of the second type (Figure 14), the central region consists of the top two levels - cells A, B, and C. In a structure of the third type (Figure 15) the central region is the second level up from the bottom - cells D, E, F, G. As the number of levels increases, the central regions of the first two types of structures will remain located at the first and the first and second levels. The central region of the third type of structure behaves somewhat differently. If the number of levels is an even number, the central region is the L/2+1 level from the top. If the number of levels in the structure is an odd number, the central region consists of two adjacent levels - the one L+1/2+1 from the top.

Therefore, in a structure of ten levels the central regions would be located in the following levels (Figure 20).

11. In reading the value of L/2 read fractions to the next integer.

Structure Type	No. of Levels	Location of Central Region in Levels from the Top
1 (Figure 13)	10	1st level
2 (Figure 14)	10	1st + 2nd levels
3 (Figure 15)	10	6th level

Figure 20

Another comparison of these structures might be made in terms of the total pattern characteristics si_x and $\sum se_{xy}$. It was shown above that for a structure of n cells both of these values have definite limits. The structures under discussion consist of 15 cells. The ranges of si_x and $\sum se_{xy}$ (see pages 23 and 25) for n=15 are shown below (Figure 21).

When n = 15

Lower Limit		Upper Limit
28	si_x	210
210	$\sum se_{xy}$	1120

Figure 21

The relative positions of the three structures in these ranges are shown below (Figure 22).

Structure Type	si_x	se_{xy}
1 (Figure 13)	28	736
2 (Figure 14)	42	594
3 (Figure 15)	98	374

Figure 22

In interpreting these figures it may be helpful to think in averages. In such terms $si_x/15$ would be the average number of neighbors per cell, and $se_{xy}/15$ would be the average distance between cells (Figure 23).

Structure Type	Average No. of neighbors	Average Distance between cells
1 (Figure 13)	1.9	49.1
2 (Figure 14)	2.8	39.6
3 (Figure 15)	6.5	24.9

Figure 23

Up to this point the distance r has not entered the discussion because the structures under consideration have consisted of closed cells only. If a structure has no open cells, r has no value. What would happen if an open cell were added? For instance, assuming that some person is to be given the function of introducing from the "outside" changes which should spread as quickly as possible throughout the organization, in the structure shown in Figure 13 it is evident that he should be attached to the organizational head - cell A, the most central region. In the structure shown in Figure 15 such an attachment would be one of the poorest to be made, since in that structure the organizational head is in the peripheral rather than in the central region.

The three types of structures discussed above are simple models which one would hardly expect to find duplicated in an existing social organization. Nevertheless, the kind of analysis that has been attempted is useful. It suggests, for instance, experimental group structures for the study of communication, and affords concepts for their structural evaluation and comparison. Recently, several trial runs of such an experimental setting were made by the writer. A group was given a task to perform which necessitated a relatively high order of communication between individuals. The pattern of communication was experimentally controlled by limiting it to a previously structured telephone system. The results of the few trials that were made suggested rather strongly that a) perception of a co-worker's ability and personality, b) degree of confidence in the successful accomplishment of the task, and c) the pace at which work could be done comfortably were all greatly affected by the structural properties of the communications pattern under which the group operated.

Another value of the kind of analysis attempted above is that it raises clearly the problems of coordination. For instance, in a typical industrial organization what may be defined as the outermost region? Would the sales force be in the outermost region? The advertising department? The employment office? The receiving room? The receptionist? Obviously, answering these questions will depend partly on what kind of communicative material is being considered. The communication pattern in a group structure will be different for a funny story than for news of a new stock issue. In the same way, the nature of "outside" will be different if one thinks of communication from the outside to the structure of baseball news as against stock market trends.

It is helpful, also, to consider the definition of "outer region". The outermost region of a structure is composed of all the cells which are "open" relative to the structure (Definition 11). An open cell of a structure is any cell whose "boundary" is not contained in the structure (Definition 3). The boundary of a cell consists of all other cells touching that cell (Definition 1). In the case of the re-

ceiving-shipping department of a company, if materials were received from and shipped to branches of the parent company only, one might conclude from the definitions given above that the department was not part of the outer region. The psychological meaning of "shipping and receiving" would probably change if this department were to become an outer region. This difference might express itself in terms of department discipline, standards of performance, work organization, and attitude toward the "customer".

DIRECTION WITHIN STRUCTURES

Just as in the case of distance, psychological direction is impossible to define in terms of Euclidian concepts except in very special circumstances; when psychological and physical movement toward a goal coincide. In many instances where the psychological goal is the reaching of a physical object, the direction of observable bodily movement may be quite different from the psychological direction to the goal. A person traversing a familiar maze may be moving directly away, physically, from the goal, although moving psychologically closer. Other types of changes of position which have a clear psychological direction - such as becoming a member of a social group - may have no physical correlate whatsoever.

In his hodological geometry, Lewin approached the problem of direction from the same basis as that of distance.

> "The distance a, b refers to the length of (the) distinguished path from a to b ..... The concept of direction in hodological space follows the same pattern. It also refers to a path between two regions A and B. Generally there are many such paths possible between two such regions and it is necessary to select one path which will determine the direction (of the path A to B)."[12]

The problem of selecting the distinguished (shortest) path has been discussed above. As in the treatment of distance, this thesis attempts the development of a concept of direction on the basis of a "minimal regions" definition of shortest path. The following ideas are developed below:

a) Steps toward or away, or neither toward or away from specified cell A_0.

b) A straight line path toward A_0.

c) A straight line path from one cell A_0 to another cell B_0.

d) Direction of movement along a straight line path from A_0 to B_0.

e) A general statement of the definition of "straight line path".

Steps Toward or Away from a Specified Cell

A cell A is selected as a point of reference, and all other cells in the structure are referred to in terms of their distance from A. This relationship may be conveniently indicated by the use of subscripts. Let the cell which is selected as the point of reference be designated as A_0 and all cells which are a distance of 1 away from A_0 be designated as A_1, etc. Thus a structure is stratified into "layers" in terms of distance from A_0. A step from any cell in the structure to an adjoining cell may be said to be toward A_0 if the step is from a higher to a lower subscript. Thus, the step A_n, A_{n-1} is a step toward A_0. The step A_n, A_{n+1} is a step away from A_0. The step A_n, A_n is a step neither toward nor away from A_0 (see Figure 24).

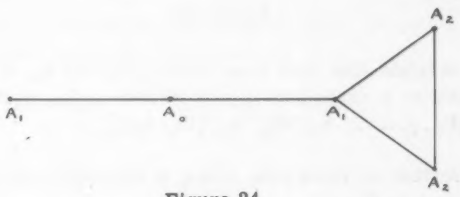


Figure 24

Step A_1 A_2 is away from A_0
Step A_2 A_1 is toward A_0
Step A_2 A_2 is neither toward nor away from A_0

A Straight Line Path Toward A_0.

Any chain of cells so arranged that successive steps along it show a decreasing subscript is considered to be a straight line path toward A_0. All such chains may be expressed in the form

$$A_n, A_{n-1}, A_{n-2}, \ldots\ldots, A_2, A_1, A_0$$

In a given structure there will be at least one straight line path from every cell not A_0 to A_0 (see Figure 25). This follows simply from the method used to assign subscripts. If a cell not A_0 bears the subscript A_x, it must by definition be touching at least one cell with a subscript of A_{x-1}. The cell A_{x-1} must, in turn, be touching a cell with the subscript A_{x-2}, etc.

12. *Op. cit.*, p. 6

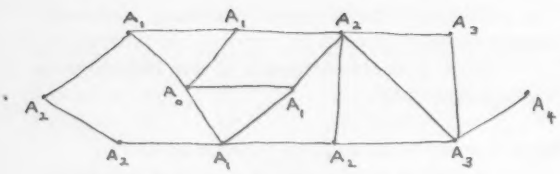


Figure 25

From A_4 there are three different straight line paths to A_0.

A Straight Line Path from A_0 to B_0.

If a structure is stratified with respect to both a cell A and a cell B, each cell in the structure will have an "A" subscript and a "B" subscript written in the form A_xB_y. In a simple chain structure of five cells the subscript would be shown in Figure 26.

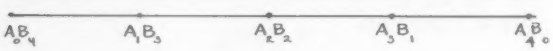


Figure 26

A straight line path from cell A_0 to cell B_0 is defined as a chain that may be written A_0B_n, A_1B_{n-1}, A_2B_{n-2}, ..., $A_{n-2}B_2$, $A_{n-1}B_1$, A_nB_0.

Direction of Movement Along A Straight Line Path from A to B.

The direction of movement along a straight line path from A to B may be indicated by assuming all A subscripts to be positive and all B subscripts to be negative. An algebraic summation of subscripts for each cell may then be made. A summation of each step of the sequence A_0B_n, A_1B_{n-1}, A_2B_{n-2} ....., $A_{n-2}B_2$, $A_{n-1}B_1$, A_nB_0 yields the following result: -n, -n+2, -n+4, ..., n-4, n-2, n. In terms of the above sequence, it may be said that in a straight line path from A to B the absolute difference between algebraically summated subscripts is equal to 2. A step along this path toward B gives a subscript differential of +2 or (-n+4)-(n+2); a step along this path toward A gives a subscript differential of -2 or (-n+2)-(-n+4).

It was stated above that there is at least one straight line path from any cell not A_0 to A_0. Since the cell B_0 is one cell of the class of cells not A_0, it follows that there is at least one straight line path from B_0 to A_0. By similar reasoning there is at least one straight line path from A_0 to B_0. It may be shown, also, that there is a path which is both a straight line path from A_0 to B_0, and a straight line path from B_0 to A_0. The demonstration is as follows: take any straight line path from A_0 to B_0. The cell B_0 will have an A subscript of some value x. By definition, there must be some cell touching this cell A_xB_0 which has the subscript of A_{x-1}. The B subscript of the cell A_{x-1} will necessarily be B_1. There must be some cell touching the cell $A_{x-1}B_1$ which has the A subscript of A_{x-2}. The B subscript of such a cell cannot be B_0 since B_0 is a unique cell in the structure. It cannot be B_1 because:

a) Any cell B_1 touches cell B_0.
b) Cell B_0 has an A subscript of x.
c) But the subscript of adjoining cells may vary only by 1.
d) Therefore, the cell A_xB_0 may not touch the cell $A_{x-2}B_1$ since the A subscripts differ by more than one.
e) Therefore, the cell A_{x-2} must bear the subscript B_2.[13]

In the same way, it may be shown that in a chain from B_0 to A_0 in which the A subscripts decrease at each step (a straight line path from B_0 to A_0), the B subscripts will increase at each step from B_0 to A_0 (a straight line path from A_0 to B_0).

Constant Differential Paths Other than Path A_0B_0.

If a straight line path between A_0 and B_0 is defined in terms of a constant subscript differential at 2, what about paths with constant differentials at some other value, if any such paths exist?[14] The problem may be stated in this way: in a structure in which no restrictions are placed upon the number of cells or their pattern of connection, how many, if any, paths with different constant subscript differentials may there be? The following analysis appears to answer this question.

In a structure that has been stratified with respect to some cell A and some cell B let the cell A_xB_y (contained in the chain A_0B_0) be selected. Since the A and B subscripts in any adjoining cell may vary only by one (or remain constant), the subscripts for all cells touching A_xB_y may be written (Figure 27).

13. It is possible, of course, for the cell $A_{x-2}B_1$ to exist in the structure, but it may not touch the cell A_xB_0.

14. Except where stated otherwise, in the discussion that follows it is assumed that the structures dealt with are stratified with respect to only two points of reference - A_0 and B_0.

A_xB_y	A_xB_{y+1}	A_xB_{y-1}
$A_{x+1}B_y$	$A_{x+1}B_{y+1}$	$A_{x+1}B_{y-1}$
$A_{x-1}B_y$	$A_{x-1}B_{y+1}$	$A_{x-1}B_{y-1}$

Subscripts of all cells touching cell A_xB_y

Figure 27

Assuming that the A subscripts are positive and the B subscripts are negative, the summation of the subscripts is shown in Figure 28.

x-y	x-y-1	x-y+1
x-y+1	x-y	x-y+2
x-y-1	x-y-2	x-y

Summation of subscripts shown in Figure 27.

Figure 28

The difference between the subscripts of each of these cells and A_xB_y may now be calculated (Figure 29).

0	-1	+1
+1	0	+2
-1	-2	0

Subscript differential for every possible step from A_xB_y

Figure 29

It may be said, therefore, that in a structure stratified with respect to two cells and with no restriction placed upon the number of cells or the pattern of connection, paths may be distinguished with constant subscript differentials of o, -1, +1, -2, +2. It is helpful at this point to draw a structure showing the subscript differentials derived above (Figure 30a, 30b).

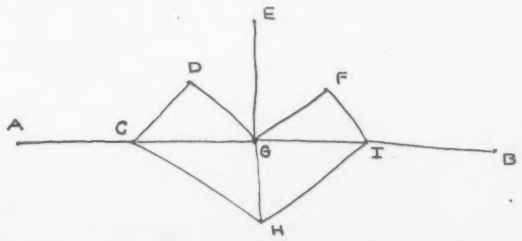


Figure 30a

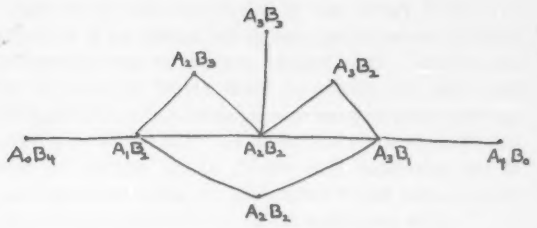


Figure 30b*

*The structures shown in figures 30a and 30b are identical. Two figures are used for convenience in indicating path differentials. For instance, the step C,D is translatable into A_1B_3, A_2B_3 which is equal to summated subscripts -2, -1. Transposing these quantities in order to get the subscript differential of the step: -1(-2) = -1+2 = +1.

The table below (Figure 31) gives some of the steps and their subscript differentials.

Step	Subscript Differential
G E	0
G H	0
G D	-1
G F	+1
G C	-2
G I	+2

Figure 31

A General Definition of Straight Line Path.

Any chain is considered to be a straight line path if it has a constant subscript differential at each step. In a given structure the subscript differential of a given step may change if the location of A_0 and/or B_0 is changed. It should be understood, therefore, that a chain is a straight line path relative to the A_0B_0 matrix that is being used.

CONCLUSION

The mathematical model presented here is admittedly in an early state of development, and the problem of coordinating the mathematical concepts to psychological data is still to be met. The main objective of this paper is to define a possible geometry for dealing with psychological space, and to explore in a limited way the consequences of a particular set of assumptions and definitions.

The fruitfulness of a model such as the one presented above may be judged not only by the questions it answers, but also by the questions it prompts one to ask. In a logical system as undeveloped as this one, the choice of "next steps" is sure to be greatly colored by personal interest however "logical" the choices are claimed to be. But the setting down of the questions that would, to the writer, be next steps is one way of indicating possible continuations.

The questions divide themselves naturally into two main groups: questions with respect to the mathematical development of the model, and questions with respect to the problem of coordination.

1) Mathematical development problems.

a) Although the distances $\underline{c}$ and $\underline{r}$ have the same limits in terms of $\underline{d}$, it has been shown that they do not vary within those limits in the same way. Why? What is the precise relationship between $\underline{c}$, $\underline{r}$, and $\underline{d}$?

b) A structure of $\underline{n}$ cells and with a constant si_x may take more than one form. Some of these froms have different $\sum se_{xy}$ values. Likewise, a structure of $\underline{n}$ cells and with a constant $\sum se_{xy}$ may take more than one form, and some of these forms have different si_x values. What precisely is the relationship between si_x and $\sum se_{xy}$?

c) There appear to be many evidences that the length of the straight line path A_0 to B_0 in a structure limits the length of straight line paths other than paths with a zero differential. Is this true, and, if so, how does the limitation operate?

2) Coordination problems.

a) it has been shown that a path within a structure may have a direction. A psychological force is also assumed to have a directional value. Can the direction of a psychological force on a person at a cell B_x toward the cell A_y be coordinated to the direction of the straight line path from B_x to A_y?

b) To what psychological entity should a cell be coordinated? If cells are coordinated to activities, goals, social position, etc., to what should regions be coordinated?

c) In order to assign directional values to paths, certain cells (A_0 and B_0) were designated as reference points. To what should these reference points be coordinated in a life space? It would appear that the coordination should be made to some part in the life space sufficiently outstanding so that all other parts are seen in relation to it. Goal regions seem an obvious choice, but many other useful coordinations seem possible.

Obviously, these are only a few of the questions that could be set down, and it is impossible to predict what course further work will actually take. For the psychologist there is an understandable urge to proceed with the business of coordination. It may be, however, that the possibility and fruitfulness of coordination are very different at different stages of development of a model, and that further mathematical development of the model is the quickest way to a useful coordination with psychological fact.